



# **Guide for the Selection of Chemical Agent and Toxic Industrial Material Detection Equipment for Emergency First Responders**

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**OFFICE OF STATE AND LOCAL GOVERNMENT  
COORDINATION & PREPAREDNESS  
SYSTEM SUPPORT DIVISION**

**Guide 100–04  
Volume I**

**March 2005**

**DEPARTMENT OF HOMELAND SECURITY**

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## **Guide for the Selection of Chemical Agent and Toxic Industrial Material Detection Equipment for Emergency First Responders, 2<sup>nd</sup> Edition**

### **Guide 100–04**

*Supersedes NIJ Guide 100–00, Guide for the Selection of Chemical Agent and Toxic Industrial Material Detection Equipment for Emergency First Responders, Volume I, dated December 2001*

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We also wish to acknowledge the InterAgency Board (IAB) for Equipment standardization and Interoperability. The IAB (made up of government and first responder representatives) was established to ensure equipment standardization and interoperability and to oversee the research and development of advanced technologies to assist first responders at the state and local levels in establishing and maintaining a robust crisis and consequence management capability.

We also sincerely thank all vendors who provided us with information about their products.

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**DISCLAIMER: Reference in this guide to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not constitute or imply the endorsement, recommendation, or favoring by the Department of Homeland Security, or any agency thereof. The views and opinions contained in this guide are those of the authors and do not necessarily reflect those of the Department of Homeland Security or any agency thereof.**

## **FOREWORD:**

The U.S. Department of Homeland Security, Office of the Secretary, Office of State and Local Government Coordination & Preparedness (SLGCP) develops and implements preparedness and prevention programs to enhance the capability of Federal, state and local governments, and the private sector to prevent, deter and respond to terrorist incidents involving chemical, biological, radiological, nuclear, and explosive (CBRNE) devices. SLGCP administers comprehensive programs of direct and grant support for training, exercises, equipment acquisition, technology transfer, and technical assistance to enhance the nation's preparedness for CBRNE acts of terrorism. The SLGCP Systems Support Division (SSD) works closely with other ODP divisions and Homeland Security professionals gaining an intimate understanding of the emergency responder technology needs and shortfalls. In addition, SSD conducts commercial technology assessments and demonstrations, and transfers equipment directly to the emergency responders. As part of the Congressional FY-03 funding, SSD was tasked with developing CBRNE technology guides and standards for the emergency responder community. This is one of several guides that will aide emergency responders in the selection of CBRNE technology.

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## Commonly Used Symbols and Abbreviations

A	ampere	hf	high frequency	N	newton
ac	alternating current	Hz	hertz	o.d.	outside diameter
AM	amplitude modulation	i.d.	inside diameter	$\Omega$	ohm
cd	candela	in	inch	p.	page
cm	centimeter	IR	infrared	Pa	pascal
CP	chemically pure	J	joule	pe	probable error
c/s	cycle per second	L	lambert	pp.	pages
d	day	L	liter	ppb	parts per billion
dB	decibel	lb	pound	ppm	parts per million
dc	direct current	lbf	pound-force	qt	quart
°C	degree Celsius	lbf·in	pound-force inch	rad	radian
°F	degree Fahrenheit	lm	lumen	rf	radio frequency
dia	diameter	ln	logarithm (base e)	rh	relative humidity
emf	electromotive force	log	logarithm (base 10)	s	second
eq	equation	M	molar	SD	standard deviation
F	farad	m	meter	sec.	Section
fc	footcandle	$\mu$	micron	SWR	standing wave ratio
fig.	Figure	min	minute	uhf	ultrahigh frequency
FM	frequency modulation	mm	millimeter	UV	ultraviolet
ft	foot	mph	miles per hour	V	volt
ft/s	foot per second	m/s	meter per second	vhf	very high frequency
g	acceleration	mo	month	W	watt
g	gram	N·m	newton meter	$\lambda$	wavelength
gal	gallon	nm	nanometer	wk	week
gr	grain	No.	number	wt	weight
H	henry	oz	ounce	yr	year
h	hour				

area=unit<sup>2</sup> (e.g., ft<sup>2</sup>, in<sup>2</sup>, etc.); volume=unit<sup>3</sup> (e.g., ft<sup>3</sup>, m<sup>3</sup>, etc.)

### ACRONYMS SPECIFIC TO THIS DOCUMENT

CA	Chemical Agent	IMS	Ion Mobility Spectrometry
CZE	Capillary Zone Electrophoresis	LCt <sub>50</sub>	(Lethal Concentration x Time) <sub>50</sub>
SF	Selection Factor	MS	Mass Spectrometry
FID	Flame Ionization Detector	NFPA	National Fire Protection Association
FPD	Flame Photometric Detector	PID	Photoionization Detection
FTIR	Fourier Transform Infrared	SAW	Surface Acoustic Wave
GC	Gas Chromatography	SCBA	Self Contained Breathing Apparatus
HPLC	High Performance Liquid Chromatography	TICs	Toxic Industrial Chemicals
IC	Ion Chromatography	TIMs	Toxic Industrial Materials
IDLH	Immediately Dangerous to Life and Health	UV-VIS	Ultraviolet-Visibility
IR	Infrared		

#### PREFIXES (See ASTM E380)

d	deci (10 <sup>-1</sup> )	da	deka (10)
c	centi (10 <sup>-2</sup> )	h	hecto (10 <sup>2</sup> )
m	milli (10 <sup>-3</sup> )	k	kilo (10 <sup>3</sup> )
$\mu$	micro (10 <sup>-6</sup> )	M	mega (10 <sup>6</sup> )
n	nano (10 <sup>-9</sup> )	G	giga (10 <sup>9</sup> )
p	pico (10 <sup>-12</sup> )	T	tera (10 <sup>12</sup> )

#### COMMON CONVERSIONS

0.30480 m = 1ft	4.448222 N = lbf
2.54 cm = 1 in	1.355818 J = 1 ft·lbf
0.4535924 kg = 1 lb	0.1129848 N m = 1 lbf·in
0.06479891 g = 1 gr	14.59390 N/m = 1 lbf/ft
0.9463529 L = 1 qt	6894.757 Pa = 1 lbf/in <sup>2</sup>
3600000 J = 1 kW·hr	1.609344 km/h = mph

$$\text{Temperature: } T_{\text{°C}} = (T_{\text{°F}} - 32) \times 5/9$$

$$\text{Temperature: } T_{\text{°F}} = (T_{\text{°C}} \times 9/5) + 32$$

## ABOUT THIS GUIDE

The Office of State and Local Government Coordination & Preparedness, System Support Division of the Department of Homeland Security is the focal point for providing support to State and local law enforcement agencies in the development of counterterrorism technology and standards, including technology needs for chemical and biological defense. In recognizing the needs of State and local emergency first responders, the Office of Law Enforcement Standards (OLES) at the National Institute of Standards and Technology (NIST), supported by the Department of Homeland Security (DHS), the Technical Support Working Group (TSWG), the U.S. Army Edgewood Chemical and Biological Center (ECBC), and the Interagency Board for Equipment Standardization and Interoperability (IAB), has developed chemical and biological defense equipment guides. The guides focused on chemical and biological equipment in areas of detection, personal protection, decontamination, and communication. This document is an update of the *Guide for the Selection of Chemical Agent and Toxic Industrial Material Detection Equipment for Emergency First Responders* (NIJ Guide 100–00) published in June 2000 and developed to assist the emergency first responder community in the evaluation and purchase of chemical detection equipment.

The long range plans continue to include two goals: (1) subject existing chemical detection equipment to laboratory testing and evaluation against a specified protocol, and (2) conduct research leading to the development of a series of documents, including national standards, user guides, and technical reports. It is anticipated that the testing, evaluation, and research processes will take several years to complete; therefore, the Department of Homeland Security will continue to maintain this guide for the emergency first responder community in order to facilitate their evaluation and purchase of chemical detection equipment.

In conjunction with this program, the additional published guides and other documents, including biological agent detection equipment, decontamination equipment, personal protective equipment, and communications equipment used in conjunction with protective clothing and respiratory equipment, will be periodically updated.

The information contained in this guide has been obtained through literature searches and market surveys. The vendors were contacted multiple times during the preparation of this guide to ensure data accuracy. In addition, the information is supplemented with test data obtained from other sources (e.g., Department of Defense) if available. It should also be noted that the purpose of this guide is not to provide recommendations but rather to serve as a means to provide information to the reader to compare and contrast commercially available detection equipment.

Technical comments, suggestions, and product updates are encouraged from interested parties. They may be addressed to the Office of Law Enforcement Standards, National Institute of Standards and Technology, 100 Bureau Drive, Stop 8102, Gaithersburg, MD 20899–8102. It is anticipated that this guide will continue to be updated periodically.

Questions relating to the specific devices included in this document should be addressed directly to the proponent agencies or the equipment manufacturers. Contact information for each equipment item included in this guide can be found in Volume II, appendix F.

# **GUIDE FOR THE SELECTION OF CHEMICAL AGENT AND TOXIC INDUSTRIAL MATERIAL DETECTION EQUIPMENT FOR EMERGENCY FIRST RESPONDERS**

This second edition guide includes information intended to be useful to the emergency first responder community in the selection of chemical agent (CA) and toxic industrial material (TIM) detection techniques and equipment for different applications. It includes an updated market survey of chemical agent and toxic industrial material technologies and commercially available detectors known to the authors as of July 2004. Brief technical discussions are presented that consider the principles of operation of the various technologies. These may be ignored by readers who find them too technical, while those wanting additional technical information can obtain it from the extensive list of references that is included in appendix B and the equipment data sheets provided in Volume II, appendix F.

## **1. INTRODUCTION**

The primary purpose of the *Guide for the Selection of Chemical Agent and Toxic Industrial Material Detection Equipment for Emergency First Responders* is to provide emergency first responders with information to aid them in the selection and utilization of chemical agent (CA) and toxic industrial material (TIM)<sup>3</sup> detection equipment. The guide is intended to be more practical than technical and provides information on a variety of factors that should be considered when purchasing and using detection equipment, including sensitivity, detection states, and portability to name a few.

Due to the large number of chemical detection equipment items identified in this guide, the guide is separated into two volumes. Volume I represents the actual guide and Volume II serves as a supplement to Volume I since it contains the detection equipment data sheets only.

The remainder of this guide (i.e., Volume I) is divided into five sections. Section 2 provides an introduction to CAs and TIMs. Specifically, it discusses nerve and blister agents by providing overviews, physical and chemical properties, routes of entry, and symptoms. It also discusses the 98 TIMs that are considered in this guide. Section 3 presents an overview of the identified CA and TIM detection technologies. For each technology, a short description is provided along with photographs of specific equipment that falls within the technology discussed. Section 4 discusses various characteristics and performance parameters that are used to evaluate the CA and TIM detection equipment in this guide. These characteristics and performance parameters are referred to as selection factors in the remainder of this guide. Sixteen selection factors have been identified. These factors were compiled by a panel of experienced scientists and engineers with multiple years of experience in CA and TIM detection and analysis, domestic preparedness, and identification of emergency first responder needs. The factors have also been shared with the emergency first responder community in order to obtain their thoughts and comments. Section 5 presents several tables that allow the reader to compare and contrast the different detection equipment utilizing the 16 selection factors.

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<sup>3</sup> Toxic industrial materials are also referred to as toxic industrial chemicals (TICs).

Two appendices are also included within this guide. Appendix A lists questions that could assist emergency first responders with selecting detection equipment. Appendix B lists the documents that were referenced in this guide.

## **2. INTRODUCTION TO CHEMICAL AGENTS AND TOXIC INDUSTRIAL MATERIALS**

The purpose of this section is to provide a description of chemical agents (CAs) and toxic industrial materials (TIMs). Section 2.1 provides the discussion of CAs and sec. 2.2 provides the discussion of TIMs.

### **2.1 Chemical Agents**

Chemical agents are chemical substances that are intended for use in warfare or terrorist activities to kill, seriously injure, or seriously incapacitate people through their physiological effects. A CA attacks the organs of the human body in such a way that it prevents those organs from functioning normally. The results are usually disabling or even fatal.

Chemical agents, when referred to in this guide, refer to nerve and blister agents only. The most common CAs are the nerve agents, GA (Tabun), GB (Sarin), GD (Soman), GF, and VX; the blister agents, HD (sulfur mustard) and HN (nitrogen mustard); and the arsenical vesicants, L (Lewisite). Other toxic chemicals such as hydrogen cyanide (characterized as a chemical blood agent by the military) or phosgene (characterized as a choking agent) are included as TIMs under sec. 2.2 of this guide.

#### **2.1.1 Nerve Agents**

This section provides an overview of nerve agents. A discussion of their physical and chemical properties, their routes of entry, and descriptions of symptoms is also provided.

##### **2.1.1.1 Overview**

Among lethal CAs, the nerve agents have had an entirely dominant role since World War II. Nerve agents acquired their name because they affect the transmission of impulses in the nervous system. All nerve agents belong to the chemical group of organo-phosphorus compounds; many common herbicides and pesticides also belong to this chemical group. Nerve agents are stable, easily dispersed, highly toxic, and have rapid effects when absorbed both through the skin and the respiratory system. Nerve agents can be manufactured by means of fairly simple chemical techniques. The raw materials are inexpensive but some are subject to the controls of the Chemical Weapons Convention and the Australia Group Agreement.

##### **2.1.1.2 Physical and Chemical Properties**

The nerve agents considered in this guide are described below. The term volatility refers to a substance's ability to become a vapor at relatively low temperatures. A highly volatile (nonpersistent) substance poses a greater respiratory hazard than a less volatile (persistent) substance.

- GA: A low volatility persistent CA that is taken up through skin contact and inhalation of the substance as a gas or aerosol.
- GB: A volatile nonpersistent CA that is mainly taken up through inhalation.

- GD: A moderately volatile CA that can be taken up by inhalation or skin contact.
- GF: A low volatility persistent CA that is taken up through skin contact and inhalation of the substance either as a gas or aerosol.
- VX: A low volatility persistent CA that can remain on material, equipment, and terrain for long periods. Uptake is mainly through the skin but also through inhalation of the substance as a gas or aerosol.

Nerve agents in the pure state are colorless liquids. Their volatility varies widely. The consistency of VX may be likened to motor oil and is therefore classified as belonging to the group of persistent CAs. Its effect is mainly through direct contact with the skin. Sarin is at the opposite extreme; being a highly volatile liquid (comparable with, for example, water), it is mainly taken up through the respiratory organs. The volatilities of GD, GA, and GF are between those of GB and VX. Table 2–1 lists the common nerve agents and some of their properties. Water is included in the table as a reference point for the nerve agents.

**Table 2–1. Physical properties of common nerve agents**

Property	GA	GB	GD	GF	VX	Water
Molecular weight	162.3	140.1	182.2	180.2	267.4	18
Density, g/cm <sup>3</sup> *	1.073	1.089	1.022	1.120	1.008	1
Boiling point, °F	464	316	388	462	568	212
Melting point, °F	18	-69	-44	-22	< -60	32
Vapor pressure, mm Hg *	0.07	2.9	0.4	0.06	0.0007	23.756
Volatility, mg/m <sup>3</sup> *	610	22 000	3 900	600	10.5	23 010
Solubility in water, % *	10	Miscible with water	2	~2	Slightly	NA

\* at 77 °F

NA: not applicable

### 2.1.1.3 Route of Entry

Nerve agents, either as a gas, aerosol, or liquid, enter the body through inhalation or through the skin. Poisoning may also occur through consumption of liquids or foods contaminated with nerve agents.

The route of entry also influences the symptoms developed and, to some extent, the sequence of the different symptoms. Generally, the poisoning works fastest when the agent is absorbed through the respiratory system rather than other routes because the lungs contain numerous blood vessels and the inhaled nerve agent can rapidly diffuse into the blood circulation and thus reach the target organs. If a person is exposed to a high concentration of nerve agent (e.g., 200 mg sarin/m<sup>3</sup>), death may occur within a couple of minutes.

The poisoning works slower when the agent is absorbed through the skin. Because nerve agents are somewhat fat-soluble, they can easily penetrate the outer layers of the skin, but it takes longer for the poison to reach the deeper blood vessels. Consequently, the first symptoms do not occur

until 20 min to 30 min after the initial exposure but subsequently, the poisoning process may be rapid if the total dose of nerve agent is high.

#### **2.1.1.4 Symptoms**

When exposed to a low dose of nerve agent, sufficient to cause minor poisoning, the victim experiences characteristic symptoms such as increased production of saliva, a runny nose, and a feeling of pressure on the chest. The pupil of the eye becomes contracted (miosis), which impairs night-vision. In addition, the capacity of the eye to change focal length is reduced and short-range vision deteriorates, causing the victim to feel pain when trying to focus on nearby objects. This is accompanied by headache. Less specific symptoms are tiredness, slurred speech, hallucinations, and nausea.

Exposure to a higher dose leads to more dramatic developments and more pronounced symptoms. Bronchoconstriction and secretion of mucus in the respiratory system leads to difficulty in breathing and to coughing. Discomfort in the gastrointestinal tract may develop into cramping and vomiting, and there may be involuntary defecation and discharge of urine. There may be excessive salivating, tearing, and sweating. If the poisoning is moderate, typical symptoms affecting the skeletal muscles may be muscular weakness, local tremors, or convulsions.

When exposed to a high dose of nerve agent, the muscular symptoms are more pronounced and the victim may suffer convulsions and lose consciousness. The poisoning process may be so rapid that symptoms mentioned earlier may never have time to develop.

Nerve agents affect the respiratory muscles and cause muscular paralysis. Nerve agents also affect the respiratory center of the central nervous system. The combination of these two effects is the direct cause of death. Consequently, death caused by nerve agents is similar to death by suffocation.

#### **2.1.2 Blister Agents (Vesicants)**

This section provides an overview of blister agents (vesicants). A discussion of their physical and chemical properties, their routes of entry, and descriptions of symptoms is also provided.

##### **2.1.2.1 Overview**

There are two major families of blister agents (vesicants): sulfur mustard (HD) and nitrogen mustard (HN), and the arsenical vesicants (L). All blister agents are persistent and may be employed in the form of colorless gases and liquids. They burn and blister the skin or any other part of the body they contact. Blister agents are likely to be used to produce casualties rather than to kill, although exposure to such agents can be fatal.

##### **2.1.2.2 Physical and Chemical Properties**

In its pure state, mustard agent is colorless and almost odorless. It earned its name as a result of an early production method that resulted in an impure product with a mustard-like smell.

Mustard agent is also claimed to have a characteristic odor similar to rotten onions. However, the sense of smell is dulled after only a few breaths so after initial exposure the odor can no longer be distinguished. In addition, mustard agent can cause injury to the respiratory system in concentrations that are so low that the human sense of smell cannot distinguish them.

At room temperature, mustard agent is a liquid with low volatility and is very stable during storage. Mustard agent can easily be dissolved in most organic solvents but has negligible solubility in water. In aqueous solutions, mustard agent decomposes into nonpoisonous products by means of hydrolysis but, since only dissolved mustard agent reacts, the decomposition proceeds very slowly. Oxidants such as chloramine, however, react violently with mustard agent, forming nonpoisonous oxidation products. Consequently, these substances are used for the decontamination of mustard agent.

Arsenical vesicants are not as common or as stable as the sulfur or nitrogen mustards. All arsenical vesicants are colorless to brown liquids. They are more volatile than mustard and have fruity to geranium-like odors. These types of vesicants are much more dangerous as liquids than as vapors. Absorption of either vapor or liquid through the skin in adequate dosage may lead to systemic intoxication or death. The physical properties of the most common blister agents are listed in table 2–2. Water is included in the table as a reference point for the blister agents.

**Table 2–2. Physical properties of common blister agents**

Property	HD	HN-1	HN-2	HN-3	L	Water
Molecular weight	159.1	170.1	156.1	204.5	207.4	18
Density, g/cm <sup>3</sup>	1.27 at 68 °F	1.09 at 77 °F	1.15 at 68 °F	1.24 at 77 °F	1.89 at 68 °F	1 at 77 °F
Boiling-point, °F	421	381	167 at 15 mm Hg	493	374	212
Freezing-point, °F	58	-61.2	-85	-26.7	64.4 to 32.18	32
Vapor pressure, mm Hg	0.072 at 68 °F	0.24 at 77 °F	0.29 at 68 °F	0.0109 at 77 °F	0.394 at 68 °F	23.756 at 77 °F
Volatility, mg/m <sup>3</sup>	610 at 68 °F	1520 at 68 °F	3580 at 77 °F	121 at 77 °F	4480 at 68 °F	23,010 at 77 °F
Solubility in water, %	<1 %	Sparingly	Sparingly	Insoluble	Insoluble	NA

NA: not applicable

### 2.1.2.3 Route of Entry

Most blister agents are relatively persistent and are readily absorbed by all parts of the body. Poisoning may also occur through consumption of liquids or foods contaminated with blister agents. These agents cause inflammation, blisters, and general destruction of tissues. In the form of gas or liquid, mustard agent attacks the skin, eyes, lungs, and gastrointestinal tract. Internal organs, mainly blood-generating organs, may also be injured as a result of mustard agent being taken up through the skin or lungs and transported into the body. Since mustard agent



gives no immediate symptoms upon contact, a delay of between 2 h and 24 h may occur before pain is felt and the victim becomes aware of what has happened. By then, cell damage has already occurred. The delayed effect is a characteristic of mustard agent.

#### **2.1.2.4 Symptoms**

In general, vesicants can penetrate the skin by contact with either liquid or vapor. The latent period for the effects from mustard is usually several hours (the onset of symptoms from vapors is 4 h to 6 h and the onset of symptoms from skin exposure is 2 h to 48 h). There is no latent period for exposure to Lewisite.

Mild symptoms of mustard agent poisoning may include aching eyes with excessive tearing, inflammation of the skin, irritation of the mucous membranes, hoarseness, coughing, and sneezing. Normally, these injuries do not require medical treatment.

Severe injuries that are incapacitating and require medical care may involve eye injuries with loss of sight, the formation of blisters on the skin, nausea, vomiting, and diarrhea together with severe difficulty in breathing. Severe damage to the eye may lead to the total loss of vision.

The most pronounced effects on inner organs are injury to the bone marrow, spleen, and lymphatic tissue. This may cause a drastic reduction in the number of white blood cells 5 d to 10 d after exposure, a condition very similar to that after exposure to radiation. This reduction of the immune defense will complicate the already large risk of infection in people with severe skin and lung injuries.

The most common cause of death as a result of mustard agent poisoning is complications after lung injury caused by inhalation of mustard agent. Most of the chronic and late effects from mustard agent poisoning are also caused by lung injuries.

## **2.2 Toxic Industrial Materials**

This section provides a general overview of TIMs as well as a list of the specific TIMs considered in this guide. Since the chemistry of TIMs is so varied, it is not feasible to discuss specific routes of entry and descriptions of symptoms.

Toxic industrial materials are chemicals other than chemical warfare agents that have harmful effects on humans. Toxic industrial materials, often referred to as toxic industrial chemicals (TICs) are used in a variety of settings such as manufacturing facilities, maintenance areas, and general storage areas. While exposure to some of these chemicals may not be immediately dangerous to life and health (IDLH), these compounds may have extremely serious effects on an individual's health after multiple low-level exposures.

### **2.2.1 General**

A TIM is a *specific type* of industrial chemical, that is, one that has a LC<sub>50</sub> value (lethal concentration for 50 % of the population multiplied by exposure time) less than 100 000

mg-min/m<sup>3</sup> in any mammalian species and is produced in quantities exceeding 30 tons per year at one production facility. Although they are not as lethal as the highly toxic nerve agents, their ability to make a significant impact on the populace is assumed to be more related to the amount of chemical a terrorist can employ on the target(s) and less related to their lethality. None of these compounds are as highly toxic as the nerve agents, but they are produced in very large quantities (multi-ton) and are readily available; therefore, they pose a far greater threat than CAs. For instance, sulfuric acid is not as lethal as the nerve agents, but it is easier to disseminate large quantities of sulfuric acid because of the large amounts that are manufactured and transported every day. It is assumed that a balance is struck between the lethality of a material and the amount of materials produced worldwide. Other toxic chemicals such as hydrogen cyanide (characterized as a chemical blood agent by the military) or phosgene (characterized as a choking agent) are included as TIMs.

Because TIMs are less lethal than the highly toxic nerve agents, it is more difficult to determine how to rank their potential for use by a terrorist. Physical and chemical properties for TIMs such as ammonia, chlorine, cyanogen chloride, and hydrogen cyanide are presented in table 2–3. Water is included in the table as a reference point for the TIMs. The physical and chemical properties for the remaining TIMs identified in this guide can be found in *International Task Force 25: Hazard From Industrial Chemicals Final Report*, April 1998. (See detailed reference in app. B).

**Table 2–3. Physical and chemical properties of toxic industrial materials**

Property	Ammonia	Chlorine	Cyanogen Chloride	Hydrogen Cyanide	Water
Molecular weight	17.03	70.9	61.48	27.02	18
Density, g/cm <sup>3</sup>	0.000 77 at 77 °F	3.214 at 77 °F	1.18 at 68 °F	0.990 at 68 °F	1 at 77 °F
Boiling-point, °F	-28	-30	55	78	212
Freezing-point, °F	-108	-150	20	8	32
Vapor pressure, mm Hg at 77 °F	7408	5643	1000	742	23.756
Volatility, mg/m <sup>3</sup>	6 782 064 at 77 °F	21 508 124 at 77 °F	2 600 000 at 68 °F	1 080 000 at 77 °F	2010 at 77 °F
Solubility in water, %	89.9	1.5	Slightly	Highly soluble	NA

### 2.2.2 Toxic Industrial Materials Rankings

TIMs are ranked into one of three categories that indicate their relative importance and assist in hazard assessment. Table 2–4 lists the TIMs with respect to their Hazard Index Ranking (High, Medium, or Low Hazard).<sup>4</sup>

<sup>4</sup> International Task Force 25: Hazard From Industrial Chemicals Final Report, April 1998.

#### **2.2.2.1 High Hazard**

High Hazard indicates a widely produced, stored, or transported TIM that has high toxicity and is easily vaporized.

#### **2.2.2.2 Medium Hazard**

Medium Hazard indicates a TIM that may rank high in some categories but lower in others such as number of producers, physical state, or toxicity.

#### **2.2.2.3 Low Hazard**

Low Hazard indicates that this TIM is not likely to be a hazard unless specific operational factors indicate otherwise.

**Table 2–4. Toxic industrial materials listed by hazard index**

High	Medium	Low
Ammonia	Acetone cyanohydrin	Allyl isothiocyanate
Arsine	Acrolein	Arsenic trichloride
Boron trichloride	Acrylonitrile	Bromine
Boron trifluoride	Allyl alcohol	Bromine chloride
Carbon disulfide	Allylamine	Bromine pentafluoride
Chlorine	Allyl chlorocarbonate	Bromine trifluoride
Diborane	Boron tribromide	Carbonyl fluoride
Ethylene oxide	Carbon monoxide	Chlorine pentafluoride
Fluorine	Carbonyl sulfide	Chlorine trifluoride
Formaldehyde	Chloroacetone	Chloroacetaldehyde
Hydrogen bromide	Chloroacetonitrile	Chloroacetyl chloride
Hydrogen chloride	Chlorosulfonic acid	Crotonaldehyde
Hydrogen cyanide	Diketene	Cyanogen chloride
Hydrogen fluoride	1,2-Dimethylhydrazine	Dimethyl sulfate
Hydrogen sulfide	Ethylene dibromide	Diphenylmethane-4,4'-diisocyanate
Nitric acid, fuming	Hydrogen selenide	Ethyl chloroformate
Phosgene	Methanesulfonyl chloride	Ethyl chlorothioformate
Phosphorus trichloride	Methyl bromide	Ethyl phosphonothioic dichloride
Sulfur dioxide	Methyl chloroformate	Ethyl phosphonic dichloride
Sulfuric acid	Methyl chlorosilane	Ethyleneimine
Tungsten hexafluoride	Methyl hydrazine	Hexachlorocyclopentadiene
	Methyl isocyanate	Hydrogen iodide
	Methyl mercaptan	Iron pentacarbonyl
	Nitrogen dioxide	Isobutyl chloroformate
	Phosphine	Isopropyl chloroformate
	Phosphorus oxychloride	Isopropyl isocyanate
	Phosphorus pentafluoride	n-Butyl chloroformate
	Selenium hexafluoride	n-Butyl isocyanate
	Silicon tetrafluoride	Nitric oxide
	Stibine	n-Propyl chloroformate
	Sulfur trioxide	Parathion
	Sulfuryl chloride	Perchloromethyl mercaptan
	Sulfuryl fluoride	sec-Butyl chloroformate
	Tellurium hexafluoride	tert-Butyl isocyanate
	n-Octyl mercaptan	Tetraethyl lead
	Titanium tetrachloride	Tetraethyl pyrophosphate
	Trichloroacetyl chloride	Tetramethyl lead
	Trifluoroacetyl chloride	Toluene 2,4-diisocyanate
		Toluene 2,6-diisocyanate

### **3. OVERVIEW OF CHEMICAL AGENT AND TIM DETECTION TECHNOLOGIES**

The applicability of CA and TIM detection equipment to potential user groups will be dependent upon the characteristics of the detection equipment, as well as the type of CA or TIM detected and the objective of the first responder unit. Numerous technologies are available for the detection of CA and TIM vapors; some technologies are available for detection and identification of liquid droplets of CAs on surfaces; and many laboratory-based technologies exist for detection of TIMs in water. The quality of analytical results from the various analyzers is dependent upon the ability to effectively sample the environment and get the sample to the analyzer.

Equipment designed for vapor detection will not be readily applicable for detection of low volatility liquid contamination on surfaces or contamination in water. In addition, vapor detection equipment could have difficulty in identifying a small amount of CA or TIM in a high background of nonhazardous environmental chemicals. For example, a chemical vapor detector may readily detect trace levels of CAs or TIMs in a rural setting such as a forest or an open field, but the same detector may not be capable of detecting the same level of CA or TIM in an urban setting such as a crowded subway station or busy city street. More urban environments typically contain many chemicals produced by everyday human activities (driving an automobile, deodorant/perfumes use, insecticide/herbicide application, etc.) that look like a CA or TIM to the detection equipment and may affect the reliability (number of false readings) of the instrument as well as its sensitivity. However, by testing the equipment prior to an emergency use, the operator can become familiar with the idiosyncrasies of the detection equipment when exposed to various environmental chemicals expected in operational areas. As technological advances continue to be made, more effective and accurate methods of detection that are less affected by environmental chemicals in operational areas will become commercially available at lower costs.

Chemical agents can be detected by several means that incorporate various technologies. The technologies discussed in this guide are grouped into three major categories: point detection, standoff detection, and analytical instruments. The technology needed for CA and TIM detection will be dependent on the CA agent or TIM used and the objective of the first responder unit.

#### **3.1 Point Detection Technologies**

Point detection technology is applicable in determining the presence of CA or TIM and can be used to map out contaminated areas if enough time is available. Point detectors can be used as warning devices to alert personnel to the presence of a toxic vapor cloud. In this scenario, the detector is placed up-wind of the first responder location. When the toxic chemical is carried towards this location, it first encounters the detector, thus sounding an alarm and allowing the first responders to don the necessary protective clothing. It should be noted that if the concentration of CA or TIM is high enough to be immediately life threatening, point detectors may not provide sufficient time to take protective measures.

Another use of a point detector would be to monitor the vapor contamination originating from a decontamination site. Point detectors can also be used during post-release triage to determine the

contamination level of each person (i.e., highly contaminated personnel, lightly contaminated personnel, and uncontaminated personnel) with the idea that all contaminated people need rapid decontamination while noncontaminated people do not need to be decontaminated. This allows for conservation of decontamination resources and prevents wasted effort on noncontaminated personnel. The following point detection techniques were identified

- Ionization/Ion Mobility Spectrometry—18 items identified.
- Flame Photometry—7 items identified.
- Infrared Spectroscopy—5 items identified.
- Electrochemistry —63 items identified.
- Colorimetric—24 items identified.
- Surface Acoustic Wave—4 items identified.
- Photoionization Detection—8 items identified.
- Thermal and Electrical Conductivity—2 items identified.
- Flame Ionization—1 item identified.
- Polymer Composite Detection Materials—1 item identified.

### **3.1.1 Ionization/Ion Mobility Spectrometry**

A detector using ionization/ion mobility spectrometry (IMS) technology is typically a stand-alone detector that samples the environment using an air pump. Contaminants in the sampled air are ionized by a radioactive source, and the resultant ions traverse the drift tube through a weak electric field toward an ion detector. The flight time, or the time it takes the ions to traverse the distance, is proportional to the size and shape of the ionized chemical species and is used for identification of the species. Analysis time ranges from several seconds to a few minutes.

Ionization of gaseous species can be achieved at atmospheric pressure. Using proton transfer reactions, charge transfer, dissociative charge transfer, or negative ion reactions such as ion transfer, nearly all chemical classes can be ionized. However, most IMS portable detectors use radioactive Beta emitters to ionize the sample.

Because IMS requires a vapor or gas sample for analysis, liquid samples must first be volatilized. The gaseous sample is drawn into a reaction chamber by a pump where a radioactive source, generally  $\text{Ni}^{63}$  (Nickel 63) or  $\text{Am}^{241}$  (Americium 241), ionizes the molecules present in the sample. The ionized air sample, including any ionized CA, is then injected into a closed drift tube through a shutter that isolates the contents of the drift tube from the atmospheric air. The drift tube has a minor electrical charge gradient that draws the sample towards a receiving electrode at the end of the drift tube. Upon ion impact, an electrical charge is generated and recorded with respect to a travel time. The travel time is measured from the introduction gate to the receiving electrode. The ions impact the electrode at different intervals providing a series of peaks and valleys in electrical charge that is usually graphed on Cartesian Coordinates. The Y-axis corresponds to the intensity of the charge received by impact of the various species that have respective travel times in the drift tube. This travel time in the drift tube and the strength of the charge gives a relative concentration of species in the sample. An example of a handheld detector using IMS technology is the Advanced Portable Detector (APD) 2000, manufactured by

Smiths Detection. This detector is shown in fig. 3–1. The market assessment identified 19 detection equipment items that utilize this technology.



***Figure 3–1. Advanced Portable Detector (APD) 2000, Smiths Detection***

The M8A1 Automatic Chemical Agent Alarm System is another example of an IMS technology CA detection and warning system. It incorporates the M43A1 detector to detect the presence of nerve agent vapors or inhalable aerosols. The M43A1 detector is an ionization product diffusion/ion mobility type detector. Air is continuously drawn through the internal sensor by a pump at a rate of approximately 1.2 L/min. Air and agent molecules are first drawn past a radioactive source ( $\text{Am}^{241}$ ) and a small percentage are ionized by the beta rays. The air and agent ions are then drawn through the baffle sections of the cell. The lighter air ions diffuse to the walls and are neutralized more quickly than the heavier agent ions that have more momentum and are able to pass through the baffled section. As a result, the collector senses a greater ion current when nerve agents are present compared to the current when only clean air is sampled. An electronic module monitors the current produced by the sensor and triggers the alarm when a critical threshold of current is reached.

### **3.1.2 Flame Photometry**

Flame photometry is based on burning ambient air with hydrogen gas. The flame decomposes any CAs or TIMs present in the air, and the characteristic radiation emitted by the particular excited molecular species during its transition to the ground state can be measured. Sulfur- and phosphorous-containing compounds introduced in a hydrogen-rich flame decompose, giving rise to excited  $\text{S}_2^*$  and  $\text{HPO}^*$  molecular species respectively, where \* represents the excited atomic or molecular state. At the elevated flame temperature, the phosphorus and sulfur emit light of specific wavelengths. These chemiluminescent emissions are isolated by appropriate narrow band optical filters and converted into measurable electrical signals by a photomultiplier tube, which produces an analog signal related to the concentration of the phosphorus- and sulfur-containing compounds in the air. Since the classical nerve agents all contain phosphorus and sulfur and mustard contains sulfur, these agents are readily detected by flame photometry. Flame photometry is sensitive and allows ambient air to be sampled directly. However, it is also prone to false alarms from interferants that contain phosphorus and sulfur. The number of false positives due to interference can be minimized using algorithms. Using a flame photometric detector (FPD) in cooperation with a gas chromatograph will further reduce the likelihood of false alarms. There are a number of gas chromatographs that use FPDs for detection purposes. Gas chromatographs are discussed in sec. 3.3.

An example of a handheld detector using this technology is the APACC Chemical Control Alarm Portable Apparatus, manufactured by Proengin SA. This detector is shown in fig. 3–2. The market assessment identified seven detection equipment items that utilize this technology.



**Figure 3–2. APACC Chemical Control Alarm Portable Apparatus, Proengin SA**

### **3.1.3 Infrared Spectroscopy**

Infrared (IR) spectroscopy is the measurement of the wavelength and intensity of the absorption of mid-infrared light by a sample. Mid-infrared light, bandwidth (2.5  $\mu\text{m}$  to 50  $\mu\text{m}$ ) and frequency (4000  $\text{cm}^{-1}$  to 200  $\text{cm}^{-1}$ ), is energetic enough to excite molecular vibrations to higher energy levels. The wavelengths of IR absorption bands are characteristic of specific types of chemical bonds and every molecule has a unique IR spectrum (fingerprint). Infrared spectroscopy finds its greatest utility for identification of organic and organometallic molecules. There are two IR spectroscopy technologies employed in point detectors: photoacoustic infrared spectroscopy (PIRS) and filter-based infrared spectroscopy. These two technologies and specific detector examples are discussed in the remainder of this section.

#### **3.1.3.1 Photoacoustic Infrared Spectroscopy**

Photoacoustic infrared spectroscopy (PIRS) detectors use the photoacoustic effect to identify and detect CA vapors. Infrared (IR) radiation is pulsed into a sample that selectively absorbs specific IR wavelengths characteristic of target gases. When the gas absorbs infrared radiation, its temperature rises, which causes the gas to expand and produces an acoustical wave that can be detected by microphones mounted inside the sample cell. Various filters are then used to selectively transmit specific IR wavelengths absorbed by the CA being monitored. Selectivity can be increased by sequentially exposing the sample to several wavelengths of light. Using multiple wavelengths to identify the unknown decreases the chance of contaminants that cause false positives and fewer interferants will be observed. Chemical agents are distinguished from interferants by the relative signal produced when several different wavelengths are sequentially transmitted to the sample.

When CA is present in the sample, an audible signal (at the frequency of modulation) is produced by the absorption of the modulated infrared light. Quantitation is possible because the acoustical wave is directly proportional to the concentration of the gas inside the cell. Although photoacoustic detectors are sensitive to external vibration and humidity, as long as the detector is calibrated in each operating environment immediately prior to sampling, selectivity will be very high. One mobile laboratory unit that utilizes photoacoustic IR spectroscopy technology is the Innova Type 1312 Multigas Monitor, from California Analytical Instruments, shown in fig. 3–3.



The market assessment identified four detection equipment items that utilize IR radiation technology.



***Figure 3–3. Innova Type 1312 Multigas Monitor, California Analytical Instruments***

### **3.1.3.2 Filter-Based Infrared Spectrometry**

Filter-based infrared spectrometry is based on a series of lenses and mirrors that directs a narrow bandpass infrared beam in a preselected path through the sample. The amount of energy absorbed by the sample is measured and stored in memory. The same sample is examined at as many as four additional wavelengths. This multiwavelength, multicomponent data is analyzed by the microprocessor utilizing linear matrix algebra. Concentrations of each component, in each sample, at each station, are used for compiling time weighted average (TWA) reports and trend displays. The data management and control software (DMCS) retains data for further analysis and longer term storage and retrieval. Thermo Environmental Products produces a portable ambient air analyzer, the Miran SaphiRe Portable Ambient Air Analyzer that is shown in fig. 3–4. The market assessment identified one detection equipment item that utilizes this technology.



***Figure 3–4. Miran SaphiRe Portable Ambient Air Analyzer, Thermo Environmental Products***

### **3.1.4 Electrochemistry**

Electrochemical detectors monitor the resistance of a thin film that changes as the film absorbs chemicals from the air or monitors a change in the electric potential of an electrode when chemicals in solution or in air are absorbed. Although electrochemical detectors are selective, they are not as sensitive as technologies such as IMS and flame photometry. Hot and cold temperatures change the rates of reactions and shift the equilibrium point of the various

reactions, which affects sensitivity and selectivity. Several of the fielded electrochemical detectors encounter problems when exposed to environmental extremes.

The inhibition of cholinesterase by nerve agents is an example of one type of reaction that can be detected by this technique. A solution containing a known amount of cholinesterase is exposed to an air sample that may contain nerve agent. If nerve agent is present, a percentage of the cholinesterase will be inhibited from reaction in the next step, that is, the addition of a solution containing a compound that will react with uninhibited cholinesterase to produce an electrochemically active product. The resulting cell potential is related to the concentration of uninhibited cholinesterase, which is related to the concentration of nerve agent present in the sampled air. Another type of electrochemical detector monitors the resistance of a thin film that increases as the film absorbs CA from the air. An example of a handheld detector using this technology is the ToxiRAE Plus Personal Gas Monitor manufactured by RAE Systems (fig. 3–5). The market assessment identified 64 items that utilize this technology.



*Figure 3–5. ToxiRAE Plus Personal Gas Monitor, RAE Systems*

### **3.1.5 Colorimetric**

Colorimetric chemistry is a wet chemistry technique formulated to indicate the presence of a CA by a chemical reaction that causes a color change when agents come in contact with certain solutions or substrates. The color change can be detected either visibly or with spectrophotometric devices. Detection tubes, papers, or tickets are common and can be used to detect nerve, blister, and blood agents. Detection paper is the least expensive and sophisticated technique for detection and can be used to quickly detect liquids and aerosols when defining a contaminated area, but it lacks specificity and can result in false-positive determinations with common chemicals such as antifreeze, brake fluid, or insect repellent. Normally, two dyes and one pH indicator are used, which are mixed with cellulose fibers in a paper without special coloring (unbleached). When a drop of chemical warfare agent is absorbed by the paper, it dissolves one of the pigments. Mustard agent dissolves a red dye and nerve agent a yellow. In addition, VX causes the indicator to turn blue that, together with the yellow, will become green/green-black.

Detector papers are generally used for testing suspect droplets or liquids on a surface. For gaseous or vaporous CAs, colorimetric tubes are available. The colorimetric tubes consist of a glass tube that has the reacting compound sealed inside. Upon use, the tips of the tubes are broken off and a pump is used to draw the sample across the reacting compound (through the tube). If a CA is present, a reaction resulting in a color change takes place in the tube. Colorimetric tubes are typically used for qualitative determinations, to verify the presence of a

CA after an alarm is received from another monitor. They can also be used to test drinking water for contamination. Draeger Safety, Inc., manufactures a number of colorimetric tubes. A picture of the Draeger CDS Kit is shown in figure 3–6. The market assessment identified 24 detection equipment items that utilize this technology.



*Figure 3–6. Draeger CDS Kit, Draeger Safety, Inc.*

### **3.1.6 Surface Acoustic Wave**

Surface acoustic wave (SAW) detectors consist of piezoelectric crystals coated with a film designed to absorb CAs from the air. The SAW sensors detect changes in the properties of acoustic waves as they travel at ultrasonic frequencies in the piezoelectric materials. Target gases are absorbed onto chemically selective surfaces, which cause a change in the resonant frequency of the piezoelectric crystal. The SAW detectors use two to six piezoelectric crystals that are coated with different polymeric films. Each polymeric film preferentially absorbs a particular class of volatile compound. For example, one polymeric film will be designed to preferentially absorb water, while other polymer films are designed to preferentially absorb different types of chemicals such as trichloroethylene, toluene, ethyl-benzene, or formaldehyde. The piezoelectric crystals detect the mass of the chemical vapors absorbed into the different, chemically selective polymeric coatings. The change in mass of the polymeric coatings causes the resonant frequency of the piezoelectric crystal to change. By monitoring the resonant frequency of the different piezoelectric crystals, a response pattern of the system for a particular vapor is generated. This response pattern is then stored in a microprocessor. When the system is operating, it constantly compares each new response pattern to the stored response pattern for the target vapor. When the response pattern for the target vapor matches the stored pattern, the system alarm is activated.

Arrays of these sensors are used to simultaneously identify and measure many different CAs. A preconcentration tube can be used to further increase detection sensitivity. These relatively inexpensive devices can be hand-held and have several advantages, including rapid response (about 2 s), 100 % reversible recovery in 5 s to 100 s, parts per trillion (ppt) sensitivity in quantitative determinations, and a long lifetime (>1 yr) for the polymer coatings. The selectivity and sensitivity of these detectors depends on the ability of the film to absorb only the suspect CAs from the sample air. Operation is simple and involves very little training or expertise. Many SAW devices use preconcentration tubes to reduce environmental interferences and increase the detection sensitivity. A detector manufactured by Microsensor Systems, Inc., that is

based upon the SAW technology is the SAW MiniCAD mkII (fig. 3–7). The market assessment identified four detection equipment items that utilize this technology.



*Figure 3–7. SAW MiniCAD mkII, Microsensor Systems*

### **3.1.7 Photoionization Detection**

Photoionization detection (PID) works by exposing a gas stream to an ultraviolet light of a wavelength with enough energy to ionize an agent molecule. If agents are present in the gas stream, they are ionized, and an ion detector then registers a voltage proportional to the number of ions produced in the gas sample, which is the concentration of the agent. Specificity of these detectors is a function of how narrow the spectral range of the exciting radiation is and on how unique that energy is to ionizing only the molecule of interest. RAE Systems, Inc., produces the MiniRAE 2000, a handheld detector that utilizes the PID technology, shown in fig. 3–8. The market assessment identified eight detection equipment items that utilize this technology.



*Figure 3–8. MiniRAE 2000, RAE Systems, Inc.*

### **3.1.8 Thermal and Electrical Conductivity**

Thermal and electrical conductivity detectors use metal oxide thermal semiconductors that measure the change in heat conductivity that occurs as a result of gas adsorption on the metal oxide surface. In addition, the change in resistance and electrical conductivity across a metal foil in the system is measured when a gas adsorbs onto the surface of the metal film. Contaminants in the atmosphere being measured will result in measurable electrical differences from the “clean” or background atmosphere. However, since different contaminants will have different

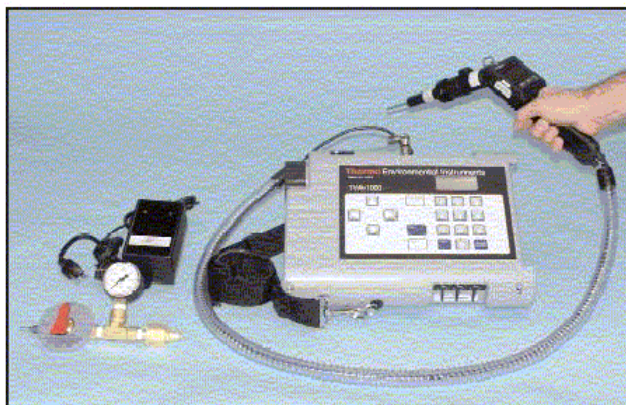
thermal conductivities and, therefore, different electrical responses from the detector, this technology is relatively nonselective. An example of a handheld detector using this technology is the Portable Odor Monitor, manufactured by Sensidyne, Inc., (fig. 3–9). The market assessment identified two detection equipment items that utilize this technology.



*Figure 3–9. Portable Odor Monitor, Sensidyne, Inc.*

### **3.1.9 Flame Ionization**

A flame ionization detector (FID) is a general-purpose detector used to determine the presence of volatile carbon-based compounds that are incinerated in a hydrogen-oxygen or hydrogen-air flame. When the carbonaceous compounds burn, ions are generated that cause an increase in the flame's baseline ion current at a collection electrode in proximity to the flame. The FIDs are not specific and require separation technology for specificity, such as a gas chromatograph. Identification of compounds is generally determined by comparison of the chromatographic retention time of a compound to that of a known standard, or to chromatographic retention indices for a series of known compounds using a standard set of chromatographic conditions. Thermo Environmental Products manufactures a unit, the TVA-1000B (FID or FID/PID) Toxic Vapor Analyzer for the specific determination of GA at 0.61 ppm (v) (above IDLH) and HD at 0.29 ppm (v) (no IDLH). The TVA-1000B is shown in fig. 3–10. The market assessment identified one detection equipment item that utilizes this technology.



*Figure 3–10. TVA-1000B (FID or FID/PID) Toxic Vapor Analyzer, Thermo Environmental Products*



### 3.1.10 Polymer Composite Detection Materials

Polymer composite detection materials consist of individual thin-film carbon-black/polymer composite chemi-resistors configured into an array. The detection materials are deposited as thin films on an alumina substrate across two electrical leads, creating conducting chemi-resistors. The output from the device is an array of resistance values measured between each of the two electrical leads for each of the detectors in the array. Nerve agent simulants, such as dimethylmethylphosphonate (DMMP) and diisopropylmethylphosphonate (DIMP), could be resolved from test analytes, including water, methanol, benzene, toluene, diesel fuel, lighter fluid, vinegar, and tetrahydrofuran, by using standard data analysis techniques to assess the collective output of the array. The Cyranose<sup>®</sup> 320, from Cyrano Sciences, pictured in fig. 3–11, is a polymer composite detection materials device. The market survey identified one detection equipment item that utilizes this technology,



*Figure 3–11. Cyranose<sup>®</sup> 320, Cyrano Sciences*

## 3.2 Standoff Detectors

Standoff detectors are used to give advance warning of a CA cloud. Standoff detectors typically use optimal spectroscopy and can detect CAs at distances as great as 5 km. Agent-free spectra are used as a baseline to compare with freshly measured spectra that may contain CA. Standoff detectors are generally difficult to operate and usually require the operator to have some knowledge of spectroscopy in order to interpret results. Passive standoff detectors collect infrared radiation emitted and/or measure infrared radiation absorbed from the background to detect CA and TIM vapor clouds. The following standoff techniques were identified.

- Fourier Transform Infrared and Forward Looking Infrared—6 items identified.
- Ultraviolet Spectroscopy—1 item identified.

### 3.2.1 Fourier Transform Infrared and Forward Looking Infrared

Fourier transform infrared (FTIR) and forward looking infrared (FLIR) spectrometers remotely monitor an area by either collecting infrared radiation emitted or measuring infrared radiation absorbed from the background to detect CA and TIM vapor clouds. In order to detect the various wavelengths emitted from the vapor clouds, FTIR spectroscopy uses an interferometer to process

the infrared radiation and FLIR spectroscopy uses a series of optical filters. Through the use of computer-based Fourier signal processing, rapid scan rates of wide ranges of wavelength and a spectrum with characteristic “fingerprint” peaks that can be used to identify the detected chemical can be generated. An example of a handheld detector using this technology is the HAWK Long Range Chemical Detector, manufactured by Bruker Daltonics (fig. 3–12). Another portable detector using this technology is the HazMatID from SensIR Technologies, shown in fig. 3–13. The market assessment identified six detection equipment items that utilize this technology.



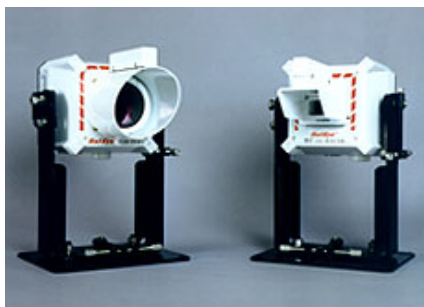
***Figure 3–12. HAWK Long Range Chemical Detector, Bruker Daltonics***



***Figure 3–13. HazMatID, SensIR Technologies***

### **3.2.2 Ultraviolet Spectroscopy**

Certain compounds have the ability to absorb ultraviolet (UV) light. Ultraviolet spectroscopy involves passing a monochromatic light through a dilute solution of the sample in a nonabsorbing solvent. The UV spectrum is generally taken by placing a dilute solution of the analyte in a silica cell and preparing a matching cell of pure solvent. The cells are placed in the spectrometer, and each cell is scanned with UV radiation. Ultraviolet spectra usually show only one broad peak indicating absorption. The intensity of the absorption is measured by the percent of the incident light that passes through the sample. The spectrum is determined by comparing the intensities of the transmitted light of the sample and the pure solvent. Characteristic UV absorptions can be useful in identifying species or assisting in determining structure. Ultraviolet spectroscopy equipment, such as the Safeye 400 Gas Detection System by Spectrex, Inc., (fig.3–14), have several advantages, including direct fast response to changes in gas concentrations, capability of large area surveillance, good cost effectiveness, and ability to remain unaffected by environmental conditions such as heat, humidity, snow, or rain. Disadvantages of standoff detectors such as the Safeye include the inability to indicate the precise concentration at a given point and dependence on an unobstructed line of sight between beam emitter and detector. The market assessment identified one detection equipment item that utilizes this technology.



*Figure 3–14. Safeye Model 400 Gas Detection System (UV), Spectrex, Inc.*

### 3.3 Analytical Instruments

The analytical instruments described in this section can be used to analyze samples as small as a few microliters or milligrams. They are designed to differentiate between and accurately measure the unique chemical properties of different molecules. Accuracy and reliability requires that only very pure reagents be used, very rigid protocol and operating procedures be followed, and careful handling be employed to prevent contamination and malfunction. Since the instruments do not display the measured data in a straightforward manner, interpretation of the measured data generally requires a technical background and extensive formal training. This typically precludes their use outside of a laboratory environment, which is staffed by technically trained people. However, some analytical instruments have been developed for field applications. The following analytical techniques were identified.

- Mass Spectrometry—15 items identified.
- Gas Chromatography—14 items identified.
- High Performance Liquid Chromatography—4 items identified.
- Ion Chromatography—1 item identified.
- Capillary Zone Electrophoresis—1 item identified.

#### 3.3.1 Mass Spectrometry

Mass spectrometry (MS) is a technique that can positively identify a CA at very low concentrations. In this technique, a volatilized sample is introduced into a vacuum chamber and ionized by an electron beam. This electron impact ionization generates a molecular ion of the compound and also causes the molecule to split into a number of fragment ions characteristic of the sample. The ionized molecules and fragments are mass analyzed by rapidly scanning a quadrupole mass filter across a wide mass range, resulting in a spectrum of intensity versus ion mass to charge ratio (equivalent to mass for the singly charged ions usually observed). The identity of the substances can then be determined by comparing the mass spectrum with library spectra and computer searching or by detailed interpretation of the ion masses and ratios. Since each molecule forms a unique set of fragments, mass spectroscopy provides positive and unambiguous identification of pure compounds. However, mixed samples may be problematic and complicate spectral interpretation. To simplify interpretation of the mass spectrum, it is often necessary to separate the components in the sample, such as in GC/MS, in which the gas chromatograph column exit is connected directly to the inlet of the mass spectrometer to permit MS analysis of mixtures separated by the GC. Two instruments that use mass spectrometry are



the Inficon Hapsite<sup>®</sup> Field Portable System manufactured by INFICON and the Agilent 6890-5973 GC/MSD from Agilent Technologies (fig. 3–15 and fig. 3–16, respectively). The market assessment identified 16 detection equipment items that utilize this technology.



**Figure 3–15. Inficon Hapsite<sup>®</sup> Field Portable System, INFICON**



**Figure 3–16. Agilent 6890-5973 GC/MSD, Agilent Technologies**

### 3.3.2 Gas Chromatography

In Gas Chromatography (GC) applications, an inert gas (mobile phase) is used to transport a volatile multicomponent sample through a long chromatographic column (packed or coated with stationary phase) in order to separate analytes in a mixture from interferences for subsequent detection. As the sample flows through the column, the various components of the sample partition between the mobile and stationary phases at different rates depending on their chemical identity or affinity for the stationary phase. The time spent (retention time) for each component of a mixture to flow through the column length will differ depending on the component's respective affinities, resulting in separation of the sample into discrete components. After exiting the column, the chemicals pass through a detector, such as a flame photometer or mass spectrometer, generating a signal proportional to the concentration. Since the retention time (rt) is characteristic of a specific compound, the rt can be used to identify components of the mixture by comparing with known rts, eliminating false alarms from similar compounds that have different rts. A preconcentrator specific to the analyte can also reduce false alarms caused by interferants. The preconcentrator passes air through an absorbent filter that traps agent molecules. The filter is then isolated from the air, connected to the GC, and heated to release any CA that may have been trapped. Two instruments that use gas chromatography are the Voyager Portable Gas Chromatograph from Photovac, Inc., and the Scentograph Plus II manufactured by Sentex Systems, Inc., shown in fig. 3–17 and fig. 3–18, respectively. The market assessment identified 15 detection equipment items that utilize this technology.



***Figure 3-17. Voyager Portable Gas Chromatograph, Photovac, Inc.***



***Figure 3-18. Scentograph Plus II, Sentex Systems, Inc.***

### **3.3.3 High Performance Liquid Chromatography**

High performance liquid chromatography (HPLC) is most useful in the detection and identification of larger molecular weight CAs, or chemicals such as BZ or LSD, and in the detection and identification of biological agents. With HPLC, compounds that do not easily volatilize can be analyzed without undergoing chemical derivatization. A solution of the sample is passed through a narrow bore column at high pressure, and species are separated based on their differential affinity for the stationary phase packing in the column. The time spent (retention time) for each component of a mixture to flow through the column length will differ depending on the component's respective affinities, resulting in separation of the sample into discrete components. As with GCs, HPLC instruments can be equipped with a variety of detectors such as ultraviolet-visible (UV-VIS) spectrometers, mass spectrometers, fluorescence spectrometers, and electrochemical detectors. Limitations to the fielding of HPLCs and their detectors are the need for a 120 V ac source, the need for high purity solvents, and the size of the instruments. Currently there is no portable HPLC unit available. The HPLC instrumentation is available from a variety of vendors such as HP1000 HPLC System from Agilent Technologies and the LC-10 HPLC System from Shimadzu Scientific Instruments. The instruments are shown in fig. 3-19 and fig. 3-20, respectively. The market assessment identified four detection equipment items that utilize this technology.



***Figure 3-19. HP1000 HPLC System, Agilent Technologies***



***Figure 3-20. LC-10 HPLC System, Shimadzu Scientific Instruments***

### 3.3.4 Ion Chromatography

A chromatographic technique closely related to HPLC is ion chromatography (IC). In this technique, ionic species can be separated, detected, and identified. Limitations to the fielding of ICs and their detectors are similar to the limitations associated with fielding HPLC instrumentation, that is, IC instruments require power requirements (120 V ac source), high purity water, and high purity chemical reagents for the preparation of buffering solutions. Like HPLC, IC instruments can use UV-VIS spectrometers, mass spectrometers, and electrochemical detectors. Ion chromatography has been successfully used in the U.S. Army Materiel Command's Treaty Verification Laboratory in the analysis of several chemical nerve agents and their degradation products. The Metrohm Model 761 Compact IC System from Metrohm-Peak, Inc., is shown in fig. 3-21. The market assessment identified one detection equipment item that utilizes this technology.



*Figure 3-21. Metrohm Model 761 Compact IC System, Metrohm-Peak, Inc.*

### 3.3.5 Capillary Zone Electrophoresis

Capillary zone electrophoresis (CZE or CE) is a chromatographic technique that can be thought of as a hybridization of gas chromatography, liquid chromatography, and ion chromatography. Rather than using a temperature gradient or a solvent gradient (as in GC or HPLC, respectively), a mobile phase containing an ionic buffer is used (as in ion chromatography). A high voltage electric field (either fixed potential or a gradient) is applied across a fused silica column similar to capillary columns used in GC.

The CZE instruments are typically configured with either a UV-VIS spectrometer or an electrochemical detector, but they can be interfaced to a mass spectrometer. The CZE instrumentation shares the same electrical requirements as HPLC and IC instruments. High purity water and chemical reagents are required but in much smaller quantities. Bio-Rad Laboratories manufactures the BioFocus 2000 CZE System (fig. 3-22). The market assessment identified one detection equipment item that utilizes this technology.



***Figure 3–22. Bio-Rad BioFocus 2000 CZE System,  
Bio-Rad Laboratories***

## 4. SELECTION FACTORS

Section 4 provides a discussion of 16 selection factors that are recommended for consideration by the emergency first responder community when selecting and purchasing CA and TIM detection equipment. These factors were compiled by a panel of experienced scientists and engineers with multiple years of experience in CA and TIM detection and analysis, domestic preparedness, and identification of emergency first responder needs. The factors have also been shared with the emergency first responder community in order to obtain their thoughts and comments.

It is anticipated that, as additional input is received from the emergency first responder community, additional factors may be added or existing factors may be modified. These factors were developed so that CA and TIM detection equipment could be compared and contrasted in order to assist with the selection and purchase of the most appropriate equipment. *It is important to note that the evaluation conducted using the 16 selection factors was based upon vendor-supplied data and no independent evaluation of equipment was conducted in the development of this guide.* The vendor-supplied data can be found in its entirety in Volume II. The results of the evaluation of the detection equipment against the 16 selection factors are provided in section 5. The remainder of this section defines each of the selection factors. Details on the manner in which the selection factors were used to assess the detectors are presented in table 4–1.

### 4.1 Chemical Agents Detected

This factor describes the ability of the equipment to detect CAs. Chemical agents, when referred to in this guide, are nerve and blister agents. Nerve agents primarily consist of GB and VX. Other nerve agents include GA, GD, and GF. Blister agents primarily consist of HD, HN, and L.

### 4.2 Toxic Industrial Materials Detected

This factor describes the ability of the equipment to detect TIMs. The TIMs considered in the development of this guide are discussed in sec. 2.2 and identified in one of three hazard indices (table 2–4).

### 4.3 Sensitivity

Sensitivity is the lowest concentration a CA or TIM can be detected at by a detector or instrument. This is also referred to as the detection limit or level of detection (LOD). Detection limits may be dependent upon the CA or TIM, the environmental conditions, or operational conditions.

Immediately dangerous to life and health (IDLH) is defined as the concentration at which self-contained breathing apparatus (SCBA) or respirators must be worn or immediate-life threatening effects will occur. The purpose of establishing an IDLH exposure level is to ensure that the worker can escape from a given contaminated environment in the event of a failure of the respiratory protection equipment. The IDLH values for the CAs and most of the 98 TIMs that are listed in table 2–4 are provided in Volume II, appendix D.

This guide bases its assessment of the sensitivity evaluation factors on the IDLH of CAs and TIMs versus the detection range of a detector. This factor does not apply to M8 and M9 paper since they require liquid contact to determine the presence of CAs or TIMs.

#### **4.4 Resistance to Interferents**

An interferent is a compound that causes a detector to either false alarm (false positive) or fail to alarm (false negative). Resistance to Interferents describes the ability of a detector or instrument to resist the effects of interferants.

#### **4.5 Response Time**

Response Time is defined as the time it takes for an instrument to collect a sample, analyze the sample, determine if an agent is present, and provide feedback.

#### **4.6 Start-Up Time**

The Start-Up Time is the time required for setting up and initiating sampling with an instrument.

#### **4.7 Detection States**

Detection States factor indicates the sample states that an instrument can detect. The sample states include vapor, aerosol, and liquid.

#### **4.8 Alarm Capability**

Alarm Capability indicates if an instrument has an audible, visible, or audible/visible alarm.

#### **4.9 Portability**

Portability is the ability of the equipment to be transported, including any support equipment required to operate the device. Two important things to consider under portability are the equipment dimensions and its weight. They determine if a single person can transport the equipment or if the equipment requires vehicular transport.

#### **4.10 Battery Needs**

Battery Needs describes if the equipment is powered by batteries with an operating life capable of sustaining activities throughout an incident. The number of batteries required for operation is also an important consideration.

#### **4.11 Power Capabilities**

Power Capabilities indicate whether specific equipment components can operate on a battery and/or ac electrical power.

#### **4.12 Operational Environment**

Operational Environment describes the type of environment required by the equipment to operate optimally. For example, some equipment is designed to operate in the field under common outdoor weather conditions and climates (i.e., extreme temperatures, humidity, rain, snow, fog, etc.). However, other equipment may require more climate-controlled conditions such as a laboratory environment.

#### **4.13 Durability**

Durability describes how rugged the equipment is, that is, how well can the equipment withstand rough handling and still operate.

#### **4.14 Unit Cost**

Unit Cost is the cost of the piece of equipment, including the cost of all support equipment and consumables.

#### **4.15 Operator Skill Level**

Operator Skill level refers to the skill level and training required for the operation of an instrument.

#### **4.16 Training Requirements**

Training Requirements is the amount of time required to instruct the operator to become proficient in the operation of the instrument. For example, higher-end equipment such as ion mobility spectrometers or SAW device requires more in-depth training such as specialized classes for operation, maintenance, and calibration of the equipment.

*Table 4-1. Selection factor key for chemical detection equipment*  
March 2005

	Chemical Agents Detected	TIMs Detected	Sensitivity	Resistance to Interferents	Response Time	Start-Up Time	Detection States	Alarm Capability	Portability	Battery Needs	Power Capabilities	Environment	Durability	Unit Cost	Operator Skills	Training
●	Detects all nerve and blister agents	Detects all of the TIMs listed	Detects at one-tenth IDLH for all detectable chemicals	Responds only to chemical agents and TIMs	Less than 10 s	Less than 30 s	Detects chemicals in all three states	Audible and visible alarm	Less than 2 lbs and handheld	Operates on standard, inexpensive, and readily available batteries for 8 h of continuous use	Battery or ac powered	Operates in all expected environments	Able to operate with rough handling	Less than \$500 per unit	No special skills or training required	No special training required
◐	Detects multiple nerve and blister agents	Detects multiple TIMs	Detects at one-tenth IDLH for one or more detectable chemicals	Has a few non-critical interferents	Between 10 s and 60 s	Between 30 s and 59 s	Detects chemicals in two states	Audible alarm only	Between 2 lbs and 5 lbs and handheld		Battery powered			Between \$500 and \$2K per unit		Less than 4 h training required
◑	Detects either the nerve or blister agent class	Detects one TIM	Detects at IDLH for all detectable chemicals	May respond to common battlefield interferents		Between 1 min and 5 min	Detects chemicals in one state	Visible alarm only	Between 5 lbs and 10 lbs	Operates on standard, inexpensive, and readily available batteries for 2 h of continuous use		Operates in most environments	Able to operate after being moved but not after rough handling	Between \$2K and \$5K per unit	No special skills but training required	Less than 8 h training required
◒			Detects at IDLH for one or more detectable chemicals	Has many interferents	Between 60 s and 2 min	Between 5 min and 30 min		Alternate alarm type	Between 10 lbs and 50 lbs		Vehicle or ac powered					
○	Detects none of the nerve or blister agents	Detects none of the TIMs listed	Does not detect IDLH levels	Does not discriminate between chemical agents/TIMs and interferents	Greater than 2 min	More than 30 min	No capability	No capability	Greater than 50 lbs	Operates on special order and expensive batteries	Powered by ac	Operation is restricted to certain environments	Must remain stationary	More than \$5K per unit	Technician required to operate equipment	More than 8 h training required

The empty cells designate that the symbol is not applicable for the selection factor.

A duplicate of this table is provided for quick reference (as table 5-14).



## **5. EQUIPMENT EVALUATION**

The market survey (refer to section 2 of Volume II) conducted for CA and TIM detection equipment identified 186 different pieces of detection equipment. The details of the market survey to include data on each piece of equipment are provided in Volume II of this guide. Section 5 documents the results of evaluating each equipment item versus the 16 selection factors. Section 5.1 defines the equipment usage categories and section 5.2 discusses the evaluation results.

### **5.1 Equipment Usage Categories**

In order to display the evaluation results in a meaningful format, the detection equipment was grouped into seven categories based on the prospective manner of usage by the emergency first responder community. These usage categories included the following:

- Handheld-portable detection equipment.
- Handheld-stationary detection equipment.
- Vehicle-mounted detection equipment.
- Fixed-site detection systems.
- Fixed-site analytical laboratory systems.
- Standoff detection systems.
- Detection systems with limited data.

The definitions for the six usage categories were extracted from the *Final Report on Chemical Detection Equipment Market Survey for Emergency Responders*. (See detailed reference in appendix B). The definitions for each of the usage categories are in the following sections.

#### **5.1.1 Handheld-Portable Detection Equipment**

Equipment defined as being human portable for mobile operations in the field. The instrument is light enough to be carried by an emergency first responder and operated while moving through a building.

#### **5.1.2 Handheld-Stationary Detection Equipment**

Equipment defined as being human portable for stationary operations. The instrument is light enough to be carried by an emergency first responder but can only be operated while stationary.

#### **5.1.3 Vehicle-Mounted Detection Equipment**

Equipment defined as being used in or from a mobile vehicle and generally uses vehicle battery for power requirements. The equipment is designed for monitoring inside or within the general vicinity of a vehicle.

#### 5.1.4 Fixed-Site Detection Systems

Equipment defined as stand-alone detection systems specifically designed to operate inside a building. The duration of operation for these instruments is indefinite, and the power requirements are met through the building infrastructure. Consumables required for continuous operation of the detection instruments (i.e., compressed gas cylinders) would need to be provided by the building management.

#### 5.1.5 Fixed-Site Analytical Laboratory Systems

Equipment defined as stand-alone detection systems requiring a means of delivering a sample to the equipment for analysis. This equipment generally requires a trained technical operator as well as extensive labor to assemble and disassemble inside a building for short duration monitoring of an area. This equipment typically performs low level monitoring of an area but has not been specifically designed for use outside a laboratory.

#### 5.1.6 Standoff Detection Systems

Equipment specifically designed to monitor the presence of CAs and TIMs that may be present in the atmosphere up to three miles away. These systems typically require one or two individuals for monitoring operations. Depending on the technique employed and the environmental conditions, these detectors can have high or low selectivity. Standoff detectors usually require vehicle transport and special setup.

#### 5.1.7 Detection Systems with Limited Data

The equipment usage category for each detection item included in this section may be handheld-portable detection equipment, handheld-stationary detection equipment, vehicle-mounted detection equipment, fixed-site detection systems, fixed-site analytical laboratory systems, or standoff detection systems. These equipment items either have too limited data to be thoroughly evaluated or were identified too late to have the data verified by the vendors.

The results of categorizing the CA and TIM detection equipment are detailed in table 5–1. Equipment was also categorized by its detection capability (CAs, TIMs, or both).

**Table 5–1. Detection equipment usage categories**

Detection Type	Detection Capability				
	CAs	TIMs	Both	Not Specified	Total
Handheld-Portable Detection Equipment	8	67	17	—	92
Handheld-Stationary Detection Equipment	12	9	10	—	31
Vehicle-Mounted Detection Equipment	2	0	3	—	5
Fixed-Site Detection Systems	3	5	8	—	16
Fixed-Site Analytical Laboratory Systems	8	—	5	—	13
Standoff Detection Systems	2	0	2	—	4
Detection Systems with Limited Data	7	7	2	9	25
<b>Total</b>	<b>42</b>	<b>88</b>	<b>47</b>	<b>9</b>	<b>186</b>

## 5.2 Evaluation Results

The evaluation results for the CA and TIM detection equipment are presented in tabular format for the 186 pieces of detection equipment identified at the time of the writing of this guide. A table is presented for each of the six usage categories with the handheld-portable and handheld-stationary detectors subdivided by detection capability. Each table includes the specific equipment and the symbol that corresponds to how the equipment item was characterized based upon each of the selection factor definitions. If data are not available to characterize a specific selection factor, TBD (to be determined) is displayed in the appropriate cell. If a selection factor is not appropriate for a specific equipment item, (NA) not applicable is used to characterize that selection factor. Table 5–2 provides the table number and associated table pages for each of the usage categories.

*Table 5–2. Evaluation results reference table*

Table Name	Table Number	Page(s)
Handheld-Portable Detection Equipment(CAs)	5–3	35
Handheld-Portable Detection Equipment(TIMs)	5–4	36–41
Handheld-Portable Detection Equipment(Both)	5–5	42–43
Handheld-Stationary Detection Equipment(CAs)	5–6	44–45
Handheld-Stationary Detection Equipment(TIMs)	5–7	46
Handheld-Stationary Detection Equipment(Both)	5–8	47
Vehicle-Mounted Detection Equipment	5–9	48
Fixed-Site Detection Systems	5–10	49–50
Fixed-Site Analytical Laboratory Systems	5–11	51–52
Standoff Detection Systems	5–12	53
Detection Systems with Limited Data	5–13	54–55
Selection Factor Key	5–14	56

### 5.2.1 Handheld-Portable Detection Equipment

There were 92 handheld-portable detection equipment items identified in the development of this guide. These 92 detection equipment items were further divided into three subcategories identifying their detection capability. Eight handheld-portable detection equipment items were capable of detecting CAs only. Sixty-seven handheld-portable detection equipment items were capable of detecting one or more of the 98 TIMs. Seventeen handheld-portable detection equipment items were capable of detecting both CAs and TIMs. Tables 5–3, 5–4, and 5–5 detail the evaluation results for all three of these subcategories, respectively.

### 5.2.2 Handheld-Stationary Detection Equipment

There were 31 handheld-stationary detection equipment items identified in the development of this guide. These 31 detection equipment items were further divided into three subcategories identifying their detection capability. Twelve handheld-stationary detection equipment items were capable of detecting CAs only. Nine detection equipment items were capable of detecting one or more of the 98 TIMs. Ten detection equipment items were capable of detecting both CAs and TIMs. Tables 5–6, 5–7, and 5–8 detail the evaluation results for all three of these subcategories.

### **5.2.3 Vehicle-Mounted Detection Equipment**

Five vehicle-mounted detection equipment items were identified in the development of this guide. Two of the three detection equipment items were capable of detecting CAs, and three was capable of detecting one or more of the 98 TIMs. Table 5–9 details the results of the vehicle-mounted detection equipment evaluation.

### **5.2.4 Fixed-Site Detection Systems**

There were 16 fixed-site detection systems identified in the development of this guide. These 15 detection systems were further divided into three subcategories identifying their detection capability. Three fixed-site detection systems were capable of detecting CAs. Five detection systems were capable of detecting one or more of the 98 TIMs. Eight detection systems were capable of detecting both CAs and TIMs. Table 5–10 details the results of the fixed-site detection systems evaluation.

### **5.2.5 Fixed-Site Analytical Systems**

There were 13 fixed-site analytical laboratory systems identified in the development of this guide. Eight of these systems were capable of detecting CAs only, and five were capable of detecting both CAs and TIMs. Table 5–11 details the results of the fixed-site analytical laboratory systems evaluation.

### **5.2.6 Standoff Detection Systems**

There were four standoff detectors identified in the development of this guide. Two standoff detection systems were capable of detecting CAs only, and two were capable of detecting both CAs and TIMs. Table 5–12 details the results of the standoff detection systems evaluation.

### **5.2.7 Detection Systems with Limited Data**

There were 25 detection systems with limited vendor supplied information. Seven of these systems were capable of detecting only CAs, seven were capable of detecting one or more of the 98 TIMs, two were capable of detecting both CAs and TIMs, and nine had no available information about detection capabilities. Table 5–13 presents the results of these detector evaluations.

The results of categorizing the CA and TIM detection equipment are detailed in table 5–1. Equipment was also categorized by its detection capability (CAs, TIMs, or both).

Table 5–14 presents the selection factor key and is a replicate of table 4–1.

**Table 5–3. Handheld-portable detection equipment (CAs)**

March 2005

ID #	Detector Name	Technology	Chemical Agents Detected	TMIs Detected	Sensitivity	Resistance to Interferents	Response Time	Start-Up Time	Detection States	Alarm Capability	Portability	Battery Needs	Power Capabilities	Operational Environment	Durability	Unit Cost	Operator Skill Level	Training Requirements
90	AP2C Chemical Agent Detector	Flame Spectrophotometer	●	○	◐	●	●	●	●	●	◐	●	◐	●	●	○	●	◐
91	AP2C-e Vapor and Liquid Agent Detector	Flame Spectrophotometer	●	○	◐	●	●	●	●	●	◐	●	◐	●	●	○	●	◐
93	APACC Chemical Control Alarm Portable Apparatus	Flame Spectrophotometer	●	○	◐	●	●	●	●	●	◐	●	●	●	●	○	●	◐
94	Remote APACC Chemical Control Alarm Portable Apparatus	Flame Spectrophotometer	●	○	◐	●	●	●	●	●	◐	●	●	●	●	○	●	◐
130	Advanced Portable Detector (APD ) 2000	Ion Mobility Spectrometry	●	○	◐	◐	◐	◐	◐	●	◐	●	●	●	●	○	◐	◐
132	Chemical Agent Monitor (CAM)	Ion Mobility Spectrometry	●	○	◐	◐	◐	◐	◐	●	◐	●	◐	●	●	○	◐	◐
138	M90-D1 Chemical Warfare Agent Detector	Ion Mobility Spectrometry	●	○	◐	◐	◐	◐	◐	●	◐	●	●	●	●	○	◐	◐
162	SAW MiniCAD mkII	Surface Acoustic Wave	●	○	○	◐	◐	◐	◐	●	●	●	◐	◐	TBD	○	◐	◐

NA (not applicable)—the specific selection factor is not applicable for the piece of equipment.

TBD (to be determined)—no current data is available to support that selection factor.

See table 5–14 for selection factor definitions.

**Table 5–4. Handheld-portable detection equipment (TIMs)**

March 2005

ID #	Detector Name	Technology	Chemical Agents Detected	TIMs Detected	Sensitivity	Resistance to Interferents	Response Time	Start-Up Time	Detection States	Alarm Capability	Portability	Battery Needs	Power Capabilities	Operational Environment	Durability	Unit Cost	Operator Skill Level	Training Requirements
10	Chrom Air Badges	Color Change Chemistry	○	●	●	●	●	●	●	●	●	NA	NA	●	●	●	●	●
11	SafeAir Monitoring System	Color Change Chemistry	○	●	●	●	●	●	●	●	●	NA	NA	●	●	●	●	●
12	Kitagawa Gas Detector Tubes	Color Change Chemistry	○	●	●	●	●	●	●	●	●	NA	NA	●	●	●	●	●
15	AutoStep Plus	Color Change Chemistry	○	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
16	SureSpot Active Sampler	Color Change Chemistry	○	●	●	●	●	●	●	●	●	●	●	TBD	●	●	●	●
17	Sensidyne Gas Detection Tubes	Color Change Chemistry	○	●	●	●	TBD	●	●	●	TBD	NA	NA	●	●	●	●	●
25	C16 PortaSens II Gas Detector	Electrochemistry	○	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
26	AMC Series 1100 Portable Gas Detector	Electrochemistry	○	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
27	PhD2 Personal Gas Detector	Electrochemistry	○	●	TBD	●	TBD	TBD	●	●	●	●	●	TBD	●	●	●	●
28	Toxi Gas Detector	Electrochemistry	○	●	TBD	●	TBD	TBD	●	●	●	●	●	TBD	●	TBD	●	●
29	Toxi Plus Gas Detector	Electrochemistry	○	●	TBD	●	TBD	TBD	●	●	●	●	●	TBD	●	TBD	●	●

NA (not applicable)—the specific selection factor is not applicable for the piece of equipment.

TBD (to be determined)—no current data is available to support that selection factor.

See table 5–14 for selection factor definitions.

**Table 5-4. Handheld-portable detection equipment (TIMs)–Continued**

March 2005

ID #	Detector Name	Technology	Chemical Agents Detected	TIMs Detected	Sensitivity	Resistance to Interferents	Response Time	Start-Up Time	Detection States	Alarm Capability	Portability	Battery Needs	Power Capabilities	Operational Environment	Durability	Unit Cost	Operator Skill Level	Training Requirements
30	Toxi Ultra Gas Detector	Electrochemistry			TBD		TBD	TBD						TBD		TBD		
31	GasAlert	Electrochemistry				TBD												
32	GasAlert Max	Electrochemistry				TBD												
33	GasAlert Micro	Electrochemistry				TBD												
34	MicroPac Plus Personal Gas Alarm	Electrochemistry																
35	MiniWarn Gas Detector	Electrochemistry																
36	Multiwarn II Gas Detector	Electrochemistry																
37	Pac III Single Gas Detector	Electrochemistry																
39	Omni-4000 Gas Detector	Electrochemistry														TBD		
40	Quadrant Portable Gas Detector	Electrochemistry												TBD		TBD		
41	Spectrum	Electrochemistry														TBD		

NA (not applicable)—the specific selection factor is not applicable for the piece of equipment.

TBD (to be determined)—no current data is available to support that selection factor.

See table 5-14 for selection factor definitions.

**Table 5–4. Handheld-portable detection equipment (TIMs)–Continued**

March 2005

ID #	Detector Name	Technology	Chemical Agents Detected	TIMs Detected	Sensitivity	Resistance to Interferents	Response Time	Start-Up Time	Detection States	Alarm Capability	Portability	Battery Needs	Power Capabilities	Operational Environment	Durability	Unit Cost	Operator Skill Level	Training Requirements
42	Target Gas Detector	Electrochemistry														TBD		
43	TX-2000 Toxic Gas Detector	Electrochemistry					TBD									TBD		
46	Haz-Alert Gas Detector	Electrochemistry			TBD		TBD						TBD					
47	ATX 612 Multi-Gas Aspirated Monitor	Electrochemistry																
48	Gas Badge Personal Gas Alarm	Electrochemistry																
49	iTX Multi-Gas Monitor	Electrochemistry				TBD	TBD	TBD						TBD	TBD			
50	LTX312/LTX311 Multi-Gas Monitor	Electrochemistry																
51	T40 Rattler Single-Gas Monitor	Electrochemistry				TBD	TBD	TBD										
52	T82 Single Gas Monitor	Electrochemistry					TBD	TBD							TBD			
53	TMX412 Multi-Gas Monitor	Electrochemistry																
55	IQ-250 Single Gas Detector	Electrochemistry			TBD			TBD										

NA (not applicable)—the specific selection factor is not applicable for the piece of equipment.

TBD (to be determined)—no current data is available to support that selection factor.

See table 5–14 for selection factor definitions.



**Table 5–4. Handheld-portable detection equipment (TIMs)–Continued**

March 2005

ID #	Detector Name	Technology	Chemical Agents Detected	TIMs Detected	Sensitivity	Resistance to Interferents	Response Time	Start-Up Time	Detection States	Alarm Capability	Portability	Battery Needs	Power Capabilities	Operational Environment	Durability	Unit Cost	Operator Skill Level	Training Requirements
56	4000 Series Compact Portable Gas Detector	Electrochemistry																
57	Logic 400 series (Model 450) Personal Air Monitor	Electrochemistry						TBD							TBD	TBD		
58	MicroMax Multigas Monitor	Electrochemistry					TBD	TBD								TBD		
59	Toxibee Personal Gas Alarm	Electrochemistry					TBD	TBD				TBD	TBD		TBD	TBD		
60	Unimax II Personal Single Gas Detector	Electrochemistry					TBD	TBD								TBD		
61	Tox-Array 1000 Gas Detector	Electrochemistry			TBD			TBD				TBD				TBD		
62	FiveStar Alarm	Electrochemistry				TBD										TBD		
63	Orion G Multigas and Leak Detector	Electrochemistry				TBD										TBD		
64	Orion Multigas and Leak Detector	Electrochemistry				TBD										TBD		
65	PULSAR Single-Gas Detector	Electrochemistry				TBD										TBD		
66	PULSAR+ Single-Gas Detector	Electrochemistry				TBD										TBD		

NA (not applicable)—the specific selection factor is not applicable for the piece of equipment.

TBD (to be determined)—no current data is available to support that selection factor.

See table 5–14 for selection factor definitions.

**Table 5–4. Handheld-portable detection equipment (TIMs)–Continued**

March 2005

ID #	Detector Name		Chemical Agents Detected	TIMs Detected	Sensitivity	Resistance to Interferents	Response Time	Start-Up Time	Detection States	Alarm Capability	Portability	Battery Needs	Power Capabilities	Operational Environment	Durability	Unit Cost	Operator Skill Level	Training Requirements
67	Tital Combustible Gas Detector	Electrochemistry				TBD										TBD		
70	MultiCheck 2000 Multi-Gas Monitor	Electrochemistry																
71	MultiLog 2000 Multi-Gas Monitor	Electrochemistry																
74	QRAE Hand Held 4 Gas Monitor	Electrochemistry																
76	VRAE Hand Held 5 Gas Surveyor	Electrochemistry																
77	Mini SA Single Gas Personal Monitor	Electrochemistry				TBD	TBD	TBD							TBD		TBD	TBD
78	Scout Multi-Gas Personal Monitor	Electrochemistry				TBD		TBD							TBD			
79	SensAir	Electrochemistry																
80	SensAir-4	Electrochemistry																
81	SensAir-Plus	Electrochemistry																
82	Genesis Portable Gas Monitor	Electrochemistry						TBD										

NA (not applicable)—the specific selection factor is not applicable for the piece of equipment.

TBD (to be determined)—no current data is available to support that selection factor.

See table 5–14 for selection factor definitions.

**Table 5–4. Handheld-portable detection equipment (TIMs)–Continued**

March 2005

ID #	Detector Name	Technology	Chemical Agents Detected	TIMs Detected	Sensitivity	Resistance to Interferents	Response Time	Start-Up Time	Detection States	Alarm Capability	Portability	Battery Needs	Power Capabilities	Operational Environment	Durability	Unit Cost	Operator Skill Level	Training Requirements
83	GT Series Portable Gas Monitor	Electrochemistry						TBD										
84	ProtectAir Personal Multi-Gas Monitor Model 8570	Electrochemistry			TBD	TBD	TBD											
86	MiniGas-XL Multi-gas Monitor	Electrochemistry					TBD	TBD								TBD		
87	Neotox-XL Single Gas Monitor	Electrochemistry					TBD	TBD								TBD		
147	VX500 Photoionization Detector	Photoionization				TBD	TBD	TBD	TBD							TBD		
148	TLV Panther Gas Detector	Photoionization				TBD												
150	2020 Photoionization Monitor	Photoionization																
164	SXC-20 VOC Monitor	Thermal and Electrical Conductivity										NA		TBD	TBD			
171	BadgeRAE Two-year Clip-on Gas Detector	Electrochemistry				TBD												
187	Dräger HazMat Simultest Kit	Color Change Chemistry				TBD		NA				NA	NA					
188	CMS Analyzer	Color Change Chemistry/Optics				TBD												
189	Dräger CMS Emergency Response Kit	Color Change Chemistry/Optics				TBD												

NA (not applicable)—the specific selection factor is not applicable for the piece of equipment.

TBD (to be determined)—no current data is available to support that selection factor.

See table 5–14 for selection factor definitions.

Table 5-5. Handheld-portable detection equipment (CAs and TIMs)

March 2005

ID #	Detector Name	Technology	Chemical Agents Detected	TIMs Detected	Sensitivity	Resistance to Interferents	Response Time	Start-Up Time	Detection States	Alarm Capability	Portability	Battery Needs	Power Capabilities	Operational Environment	Durability	Unit Cost	Operator Skill Level	Training Requirements
5	ChemSentry™ 150C Point Chemical Vapor Detector System	Surface Acoustic Wave and Electrochemical Cell	●	◐	TBD	◐	TBD	TBD	◐	◐	◐	●	●		●	TBD	TBD	TBD
13	MSA Gas Detection Tubes	Color Change Chemistry	●	◐	◐	●	●	◐	◐	◐	●	●	◐	●	◐	TBD	●	◐
73	MultiRAE Plus Gas Detector	Electrochemical and/or PID	●	◐	◐	◐	○	◐	◐	●	●	●	◐	◐	●	◐	◐	◐
75	ToxiRAE Plus Personal Gas Monitor	Electrochemical and/or PID	●	◐	◐	◐	○	◐	◐	●	●	●	◐	◐	●	◐	◐	◐
95	TIM's toxic industrial materials detector	Flame spectrophotometer	●	◐	◐	●	●	●	●	●	●	◐	●	●	○	●	◐	
100	ChemDisk Diffusive Sampler	GC or UV-VIS Spectroscopy	●	◐	◐	◐	○	◐	◐	○	●	●	◐	◐	◐	○	TBD	TBD
126	IMS 2000E Chemical Warfare Agent Detector	Ion Mobility Spectrometry	●	◐	◐	◐	◐	◐	◐	●	◐	●	●	●	●	○	◐	◐
127	Rapid Alarm & Identification Device-Mobile (RAID-M)	Ion Mobility Spectrometry	●	◐	◐	◐	◐	◐	◐	●	◐	◐	●	●	●	○	◐	◐
136	Lightweight Chemical Detector (LCD)	Ion Mobility Spectrometry	●	◐	◐	◐	●	●	◐	●	●	●	◐	◐	●	○	●	◐
137	Manportable Chemical Agent Detector (MCAD)	Ion Mobility Spectrometry	●	◐	◐	◐	◐	●	◐	●	●	●	◐	◐	●	◐	●	◐

NA (not applicable)—the specific selection factor is not applicable for the piece of equipment.

TBD (to be determined)—no current data is available to support that selection factor.

See table 5-14 for selection factor definitions.

**Table 5–5. Handheld-portable detection equipment (CAs and TIMs)–Continued**  
March 2005

ID #	Detector Name	Technology	Chemical Agents Detected	TIMs Detected	Sensitivity	Resistance to Interferents	Response Time	Start-Up Time	Detection States	Alarm Capability	Portability	Battery Needs	Power Capabilities	Operational Environment	Durability	Unit Cost	Operator Skill Level	Training Requirements
152	MiniRAE 2000	Ion Mobility Spectrometry	●	◐	◐	○	●	◐	◐	●	●	●	◐	◐	●	◐	◐	◐
153	ppbRAE	Photoionization	●	◐	◐	○	●	◐	◐	●	●	●	◐	◐	●	○	◐	◐
165	HAZMATCAD Plus	Surface Acoustic Wave	●	◐	◐	◐	◐	◐	◐	●	●	●	◐	◐	●	○	●	◐
166	ECAM - Enhanced Chemical Agent Monitor	Ion Mobility Spectrometry	●	◐	◐	◐	◐	●	◐	●	●	●	◐	●	●	○	●	◐
167	SABRE 2000	Ion Mobility Spectrometry	●	◐	◐	◐	◐	●	◐	●	●	●	◐	●	●	○	●	◐
170	ChemPro100	Ion Mobility Spectrometry	●	◐	◐	◐	◐	◐	◐	●	●	●	●	●	●	TBD	◐	◐
190	Draeger Multi-IMS	Ion Mobility Spectrometry	●	◐	◐	◐	●	◐	◐	●	●	●	◐	●	●	○	◐	◐

NA (not applicable)—the specific selection factor is not applicable for the piece of equipment.

TBD (to be determined)—no current data is available to support that selection factor.

See table 5–14 for selection factor definitions.

**Table 5-6. Handheld-stationary detection equipment (CAs)**

March 2005

ID #	Detector Name	Technology	Chemical Agents Detected	TTMs Detected	Sensitivity	Resistance to Interferents	Response Time	Start-Up Time	Detection States	Alarm Capability	Portability	Battery Needs	Power Capabilities	Operational Environment	Durability	Unit Cost	Operator Skill Level	Training Requirements
2	3-Way Paper, Chemical Agent Liquid Detectors	Color Change Chemistry	●	○	TBD	◐	●	●	◐	◐	●	NA	NA	●	●	●	●	◐
8	HazCat MicroCat/WMD Kit	Color Change Chemistry	●	○	●	NA	○	○	◐	○	◐	●	◐	◐	◐	○	◐	○
9	HazCat WMD Kit	Color Change Chemistry	●	○	●	◐	○	○	◐	○	◐	NA	NA	◐	◐	◐	◐	○
14	No. 1 Mark 1 Detector Kit	Color Change Chemistry	●	○	◐	◐	TBD	◐	◐	◐	●	NA	NA	TBD	TBD	●	●	◐
18	ABC-M8 VGH Chemical Agent Detector Paper	Color Change Chemistry	●	○	TBD	◐	◐	●	◐	◐	●	NA	NA	◐	●	●	●	●
21	M9 Chemical Agent Detector Paper	Color Change Chemistry	●	○	TBD	◐	◐	●	◐	◐	●	NA	NA	◐	●	●	●	●
107	Hapsite	GC with Mass Spectrometry	●	TBD	TBD	●	○	○	◐	◐	◐	●	◐	●	○	○	○	○
110	Scentograph Plus II Gas Chromatography	Gas Chromatography	●	○	◐	◐	○	◐	◐	◐	◐	◐	◐	◐	◐	○	○	○

NA (not applicable)—the specific selection factor is not applicable for the piece of equipment.

TBD (to be determined)—no current data is available to support that selection factor.

See table 5-14 for selection factor definitions.

**Table 5–6. Handheld-stationary detection equipment (CAs)–Continued**

March 2005

ID #	Detector Name	Technology	Chemical Agents Detected	TIMs Detected	Sensitivity	Resistance to Interferents	Response Time	Start-Up Time	Detection States	Alarm Capability	Portability	Battery Needs	Power Capabilities	Operational Environment	Durability	Unit Cost	Operator Skill Level	Training Requirements
111	Scentoscreen (Gas Chromatography) with Argon Ionization Detector	GC with Mass Spectrometry	<div></div>	TBD	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>
156	Innova Type 1312 Multigas Monitor	Photoacoustic Infrared (PIR) Spectroscopy	<div></div>	TBD	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>
157	Innova Type 1314 Multigas Monitor	Photoacoustic Infrared (PIR) Spectroscopy	<div></div>	TBD	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>
172	Civil Defense Kit	Colorimetric detector tubes	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	TBD	<div></div>	<div></div>

NA (not applicable)—the specific selection factor is not applicable for the piece of equipment.

TBD (to be determined)—no current data is available to support that selection factor.

See table 5–14 for selection factor definitions.



**Table 5–7. Handheld-stationary detection equipment (TIMs)**

March 2005

ID #	Detector Name	Technology	Chemical Agents Detected	TIMs Detected	Sensitivity	Resistance to Interferents	Response Time	Start-Up Time	Detection States	Alarm Capability	Portability	Battery Needs	Power Capabilities	Operational Environment	Durability	Unit Cost	Operator Skill Level	Training Requirements
7	HazCat Chemical Identification Kit	Color Change Chemistry										NA	NA					
22	Chemkey TLD Toxic Gas Monitor	Color Change Chemistry				TBD									TBD	TBD		
23	CM4 Gas Monitor (Color Change Chemistry)	Color Change Chemistry				TBD						NA			TBD	TBD		
85	Gas Beacon/Gas Leader	Electrochemistry					TBD	TBD								TBD		
109	Voyager Gas Chromatography	Gas Chromatography										TBD						
163	Portable Odor Monitor	Thermal and Electrical Conductivity														TBD		
168	SAFEYE Model 400 Gas Detection System	Ultraviolet Spectroscopy																
186	Draeger Hazmat Kit	Color Change Chemistry										NA	NA					

NA (not applicable)—the specific selection factor is not applicable for the piece of equipment.

TBD (to be determined)—no current data is available to support that selection factor.

See table 5–14 for selection factor definitions.



**Table 5–8. Handheld-stationary detection equipment (CAs and TIMs)**

March 2005

ID #	Detector Name	Technology	Chemical Agents Detected	TIMs Detected	Sensitivity	Resistance to Interferents	Response Time	Start-Up Time	Detection States	Alarm Capability	Portability	Battery Needs	Power Capabilities	Operational Environment	Durability	Unit Cost	Operator Skill Level	Training Requirements
3	Chemical Agent Detector Kit	Color Change Chemistry	●	◐	◐	TBD	○	◐	◐	◐	●	NA	NA	●	●	●	◐	◐
4	M256A1 Kit Color Change Chemistry	Color Change Chemistry	●	◐	◐	◐	○	●	◐	◐	●	NA	NA	●	●	●	●	●
6	Draeger CDS Kit	Color Change Chemistry	●	◐	◐	●	○	◐	◐	◐	●	NA	NA	◐	●	◐	●	◐
19	M18A2 Chemical Agent Detector Kit	Color Change Chemistry	●	◐	◐	◐	○	●	●	◐	◐	NA	NA	●	●	●	◐	◐
20	M272 Water Kit Color Change	Color Change Chemistry	●	◐	◐	◐	○	●	◐	◐	◐	NA	NA	●	●	●	●	●
122	HazMatID	FTIR Spectroscopy	●	◐	◐	◐	◐	◐	◐	◐	◐	◐	●	◐	●	○	◐	○
123	TravellIR HCI	FTIR Spectroscopy	●	◐	◐	◐	◐	◐	◐	◐	◐	◐	●	◐	●	○	◐	○
124	Miran SaphIRe Portable Ambient Air Analyzer	Infrared Spectroscopy (filter based )	●	◐	◐	TBD	◐	◐	◐	◐	◐	TBD	◐	TBD	●	○	●	◐
159	4200 Vapor Detector	GC with SAW	●	◐	◐	◐	◐	◐	●	◐	◐	NA	○	◐	TBD	○	◐	◐
160	7100 Vapor Detector	GC with SAW	●	◐	◐	◐	◐	◐	●	◐	◐	NA	○	◐	TBD	○	◐	◐

NA (not applicable)—the specific selection factor is not applicable for the piece of equipment.

TBD (to be determined)—no current data is available to support that selection factor.

See table 5–14 for selection factor definitions.

**Table 5–9. Vehicle-mounted detection equipment**

March 2005

ID #	Detector Name	Technology	Chemical Agents Detected	TIAs Detected	Sensitivity	Resistance to Interferents	Response Time	Start-Up Time	Detection States	Alarm Capability	Portability	Battery Needs	Power Capabilities	Operational Environment	Durability	Unit Cost	Operator Skill Level	Training Requirements
92	AP2C-V Mobile Detector	Flame Spectrophotometer and Agent Dose Meter	●	○	◐	●	●	●	●	●	◐	NA	◐	●	●	○	●	◐
105	CT-1128 GC/MS	GC with MS	●	◐	◐	●	○	○	◐	○	○	TBD	●	◐	●	○	○	○
146	Chemical Biological Mass Spectrometer	MS—Ion Trap MS/MS	●	○	◐	●	◐	◐	●	◐	NA	◐	●	●	●	○	◐	◐
182	Airsense Model—GDA-II GDA-II-NA	IMS, PID, ECC, and SC	●	◐	◐	●	○	◐	◐	●	○	●	●	●	○	○	○	○
183	MINICAMS Series 3000 Continuous Air Monitoring Systems	GC and sample collection	●	◐	◐	TBD	○	TBD	◐	◐	◐	NA	○	◐	●	TBD	TBD	TBD

NA (not applicable)—the specific selection factor is not applicable for the piece of equipment.

TBD (to be determined)—no current data is available to support that selection factor.

See table 5–14 for selection factor definitions.

*Table 5–10. Fixed-site detection systems*  
March 2005

ID #	Detector Name	Technology	Chemical Agents Detected	TMIs Detected	Sensitivity	Resistance to Interferents	Response Time	Start-Up Time	Detection States	Alarm Capability	Portability	Battery Needs	Power Capabilities	Operational Environment	Durability	Unit Cost	Operator Skill Level	Training Requirements
44	Model TS400 Toxic Gas Detector	Electrochemistry	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	TBD	TBD	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>
68	Toxgard II Series Gas Monitors	Electrochemistry	<div></div>	<div></div>	<div></div>	TBD	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	TBD	<div></div>	<div></div>
69	Ultima X Series Gas Monitors	Electrochemistry	<div></div>	<div></div>	<div></div>	TBD	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	TBD	<div></div>	<div></div>
89	ADLIF Fixed continuous chemical detector	Flame Spectrophotometer and Agent Dose Meter	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	NA	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>
106	Automatic Continuous Environmental Monitor (ACEM) 900 GC	Gas Chromatography	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	TBD	<div></div>	<div></div>	<div></div>	NA	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>
128	Stationary Rapid Alarm & Identification Device (RAID-S)	Ion Mobility Spectrometry	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	NA	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>
129	AirSentry	Ion Mobility Spectrometry	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	TBD	<div></div>	NA	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	TBD	<div></div>
131	Centurion	Ion Mobility Spectrometry	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	NA	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>

NA (not applicable)—the specific selection factor is not applicable for the piece of equipment.

TBD (to be determined)—no current data is available to support that selection factor.

See table 5–14 for selection factor definitions.

*Table 5–10. Fixed-site detection systems—Continued*

March 2005

ID #	Detector Name	Technology	Chemical Agents Detected	THMs Detected	Sensitivity	Resistance to Interferents	Response Time	Start-Up Time	Detection States	Alarm Capability	Portability	Battery Needs	Power Capabilities	Operational Environment	Durability	Unit Cost	Operator Skill Level	Training Requirements
133	GID-2A Chemical Detector	Ion Mobility Spectrometry	●	●	●	●	●	●	●	●	●	NA	○	●	●	○	●	●
134	GID-3, Chemical Agent Detection System	Ion Mobility Spectrometry	●	●	●	●	●	●	●	●	●	●	●	●	●	TBD	●	●
135	GID-3 (24/7), Chemical Agent Detection System	Ion Mobility Spectrometry	●	●	●	●	●	●	●	●	●	●	●	●	●	TBD	●	●
139	Questor Continuous Multiple Chemical Agent Monitoring System	Mass Spectrometry	●	○	●	TBD	TBD	TBD	●	●	TBD	NA	○	○	●	○	●	●
158	Chemgard Infrared Gas Monitors	Photoacoustic Infrared (PIR) Spectroscopy	○	●	●	TBD	●	○	●	●	●	NA	○	●	○	TBD	●	●
161	CW Sentry Plus	Surface Acoustic Wave	●	●	●	●	●	●	●	●	●	NA	○	●	○	○	●	●
169	ACADA	Ion Mobility Spectrometry	●	●	●	●	●	●	●	●	●	●	●	●	●	TBD	●	●
175	Dräger IMS 5100	Ion Mobility Spectrometry	●	●	●	●	●	●	●	●	●	NA	○	○	●	TBD	●	●

NA (not applicable)—the specific selection factor is not applicable for the piece of equipment.

TBD (to be determined)—no current data is available to support that selection factor.

See table 5–14 for selection factor definitions.

**Table 5–11. Fixed-site analytical laboratory systems**

March 2005

ID #	Detector Name	Technology	Chemical Agents Detected	TIMs Detected	Sensitivity	Resistance to Interferents	Response Time	Start-Up Time	Detection States	Alarm Capability	Portability	Battery Needs	Power Capabilities	Operational Environment	Durability	Unit Cost	Operator Skill Level	Training Requirements
72	AreaRAE Wireless Gas Detection System	Electrochemical and/or PID	●	◐	◐	◐	○	◐	◐	●	◐	●	◐	◐	●	◐	◐	◐
96	Automatic Continuous Air Monitoring System (ACAMS)	GC with Flame Photometry	●	○	◐	◐	○	○	◐	●	○	NA	○	TBD	●	○	○	○
97	Agilent 6850	GC with Flame Photometry	●	◐	◐	◐	○	○	◐	●	○	NA	○	◐	●	TBD	◐	◐
98	Agilent 6890N	GC with Flame Photometry	●	◐	◐	◐	○	○	◐	●	○	NA	○	◐	●	TBD	◐	◐
99	Agilent 6890N-5973N	GC with MS	●	◐	◐	◐	○	○	◐	○	○	NA	○	◐	●	TBD	○	○
103	Bruker Viking 573	GC with MS	●	TBD	◐	●	○	○	◐	○	○	NA	○	○	◐	○	○	○
140	API 150 EX	Mass Spectrometry	●	TBD	TBD	◐	○	◐	◐	○	○	NA	○	○	◐	TBD	○	○
141	API2000 Triple Quadrupole LC/MS/MS System	Mass Spectrometry	●	TBD	TBD	◐	○	◐	◐	○	○	NA	○	○	◐	TBD	○	○

NA (not applicable)—the specific selection factor is not applicable for the piece of equipment.

TBD (to be determined)—no current data is available to support that selection factor.

See table 5–14 for selection factor definitions.

**Table 5–11. Fixed-site analytical laboratory systems–Continued**  
March 2005

ID #	Detector Name	Technology	Chemical Agents Detected	TMIs Detected	Sensitivity	Resistance to Interferents	Response Time	Start-Up Time	Detection States	Alarm Capability	Portability	Battery Needs	Power Capabilities	Operational Environment	Durability	Unit Cost	Operator Skill Level	Training Requirements
142	API3000 Triple Quadrupole LC/MS/MS System	Mass Spectrometry	●	TBD	TBD	◐	○	◐	◐	○	○	NA	○	○	◐	TBD	○	○
143	API4000 Triple Quadrupole LC/MS/MS System	Mass Spectrometry	●	TBD	TBD	◐	○	◐	◐	○	○	NA	○	○	◐	TBD	○	○
144	API QSTAR XL Hybrid LC/MS/MS System	Mass Spectrometry	●	TBD	TBD	◐	○	◐	◐	○	○	NA	○	○	◐	TBD	○	○
145	QTRAP Hybrid Linear Ion Trap - Triple Quadrupole LC/MS/MS System	Mass Spectrometry	●	TBD	TBD	◐	○	◐	◐	○	○	NA	○	○	◐	TBD	○	○
192	Dräger GC-IMS 5700	Ion Mobility Spectrometry/Integrated CG Column	●	◐	◐	◐	◐	◐	◐	◐	◐	NA	○	○	◐	TBD	◐	◐

NA (not applicable)—the specific selection factor is not applicable for the piece of equipment.

TBD (to be determined)—no current data is available to support that selection factor.

See table 5–14 for selection factor definitions.

*Table 5-12. Standoff detection systems*  
March 2005

ID #	Detector Name	Technology	Chemical Agents Detected	TIMs Detected	Sensitivity	Resistance to Interferents	Response Time	Start-Up Time	Detection States	Alarm Capability	Portability	Battery Needs	Power Capabilities	Operational Environment	Durability	Unit Cost	Operator Skill Level	Training Requirements
38	RAM 2000	Active FTIR	●	◐	◐	◐	●	◐	◐	●	○	NA	○	◐	◐	○	◐	◐
118	HAWK Long Range Chemical Detector	Passive FTIR	●	◐	◐	●	●	◐	◐	●	○	●	●	●	●	○	◐	◐
120	Joint Service Lightweight Standoff	FTIR	●	TBD	○	●	◐	◐	◐	●	◐	NA	◐	●	●	TBD	◐	TBD
121	M21 Automatic Chemical Agent Alarm	FTIR	●	○	○	◐	◐	◐	◐	●	○	NA	◐	●	●	TBD	◐	◐

NA (not applicable)—the specific selection factor is not applicable for the piece of equipment.

TBD (to be determined)—no current data is available to support that selection factor.

See table 5-14 for selection factor definitions.

**Table 5–13. Detection systems with limited data**  
March 2005

ID #	Detector Name	Transportability	Technology	Chemical Agents Detected	TTMs Detected	Sensitivity	Resistance to Interferents	Response Time	Start-Up Time	Detection States	Alarm Capability	Portability	Battery Needs	Power Capabilities	Operational Environment	Durability	Unit Cost	Operator Skill Level	Training Requirements
1	Bio-Rad BioFocus 2000 System CZE	Fixed-Site Analytical Laboratory	CZE	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
45	Model TS420 Oxygen Deficiency Detector	Fixed-Site Detection	Electrochemistry	TBD	TBD	TBD	NA		TBD		TBD		TBD	TBD			TBD		TBD
54	WorksAlone 2/Transmitter 2	Fixed-Site Detection	Electrochemistry				TBD		TBD			TBD	TBD	TBD			TBD		
101	Infrared Detector for Gas Chromatograph	Fixed-Site Analytical Laboratory	GC with IR Spectrometry		TBD	TBD		TBD					NA		TBD	TBD			
102	Trace Ultra High Sensitivity	Fixed-Site Analytical Laboratory	GC with FTIR		TBD		TBD				TBD	TBD	NA			TBD	TBD		
104	Miniature Air Sampling System (MASS)	Fixed-Site Analytical Laboratory	GC			NA	NA		TBD		TBD		NA		TBD	TBD	TBD		
112	Dual-Flame Photometric Detector	Fixed-Site Analytical Laboratory	GC with Flame Photometry		TBD	TBD							NA		TBD	TBD	TBD		
113	Saturn 2000	Fixed-Site Analytical Laboratory	GC with MS		TBD	TBD					TBD		NA		TBD	TBD			
114	Agilent 1100 Series LC	Fixed-Site Analytical Laboratory	HPLC			TBD	TBD	TBD	TBD		TBD	TBD	TBD	TBD	TBD		TBD		
115	Perkin-Elmer Turbo LC Plus HPLC System	Fixed-Site Analytical Laboratory	HPLC	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
116	Shimadzu LC-10 HPLC System	Fixed-Site Analytical Laboratory	HPLC	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
117	Varian ProStar Analytical HPLC System	Fixed-Site Analytical Laboratory	HPLC	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
125	Metrohm Model 1761 Compact IC System	Fixed-Site Analytical Laboratory	IC			TBD	TBD	TBD	TBD				NA						
149	MSA Passport II PID Monitor	Handheld Portable	Photoionization				TBD	TBD	TBD		TBD	TBD	TBD	TBD	TBD	TBD			TBD
154	TVA-1000B Toxic Vapor Analyzer	Handheld Stationary	Flame Ionization /Photoionization		TBD		TBD		TBD		TBD				TBD	TBD	TBD		

NA (not applicable)—the specific selection factor is not applicable for the piece of equipment.

TBD (to be determined)—no current data is available to support that selection factor.

See table 5–14 for selection factor definitions.



**Table 5–13. Detection systems with limited data–Continued**  
March 2005

ID #	Detector Name	Transportability	Technology	Chemical Agents Detected	TTMs Detected	Sensitivity	Resistance to Interferents	Response Time	Start-Up Time	Detection States	Alarm Capability	Portability	Battery Needs	Power Capabilities	Operational Environment	Durability	Unit Cost	Operator Skill Level	Training Requirements
173	CT-1128 GC-MS Portable	Vehicle Mounted	GC with Quadrupole MS	TBD	TBD	TBD	TBD	TBD	TBD	TBD	○	TBD	TBD	TBD	●	TBD	TBD	TBD	
174	The HazMat SmartM-8 Simple Nerve Agent Detection	Handheld Portable	Color Change Chemistry	◐	TBD	TBD	TBD	●	●	◐	◐	●	NA	NA	TBD	●	TBD	●	TBD
176	Portable Isotopic Neutron-Spectroscopy Chemical Assay System	Vehicle Mounted	Ge Detector Plus Portable Spectrometer	●	◐	TBD	TBD	○	TBD	◐	TBD	○	●	TBD	TBD	●	TBD	TBD	TBD
177	Sensit®Gold CGI	Handheld Portable	Electrochemistry	TBD	◐	TBD	TBD	TBD	TBD	◐	●	TBD	●	◐	TBD	●	TBD	TBD	TBD
178	Commander from IST Aim	Handheld Portable	Color Change Chemistry	○	◐	◐	TBD	TBD	TBD	◐	●	●	●	◐	●	●	TBD	TBD	TBD
179	Proficiency Certification Test (PCT) Kit	Handheld Stationary	Electrochemistry (Training Kit)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
180	Cyranose® 320	Handheld Portable	Polymer Composite Sensor	TBD	◐	TBD	TBD	TBD	●	◐	TBD	●	●	●	●	TBD	TBD	TBD	TBD
181	IlluminatIR ML Package	Vehicle Mounted	IR Spectrometer	●	TBD	TBD	◐	◐	◐	●	◐	○	NA	◐	○	◐	○	◐	○
184	ToxAlert TOXCONTROL Gas Detection Systems	Not specified	Electrochemical, metal-oxide semiconductor, and IR	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
185	Minotaur 500	Not specified	MS/MS or MSn	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
191	DAXEL 2C	Vehicle Mounted, Stand-alone	GC, Pyrolysis, and MS	◐	◐	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD

NA (not applicable)—the specific selection factor is not applicable for the piece of equipment.

TBD (to be determined)—no current data is available to support that selection factor.

See table 5–14 for selection factor definitions.

**Table 5-14. Selection factor key for chemical detection equipment**  
March 2005

	Chemical Agents Detected	TIMs Detected	Sensitivity	Resistance to Interferents	Response Time	Start-Up Time	Detection States	Alarm Capability	Portability	Battery Needs	Power Capabilities	Environment	Durability	Unit Cost	Operator Skills	Training
●	Detects all nerve and blister agents	Detects all of the TIMs listed	Detects at one-tenth IDLH for all detectable chemicals	Responds only to chemical agents and TIMs	Less than 10 s	Less than 30 s	Detects chemicals in all three states	Audible and visible alarm	Less than 2 lbs and handheld	Operates on standard, inexpensive, and readily available batteries for 8 h of continuous use	Battery or ac powered	Operates in all expected environments	Able to operate with rough handling	Less than \$500 per unit	No special skills or training required	No special training required
◐	Detects multiple nerve and blister agents	Detects multiple TIMs	Detects at one-tenth IDLH for one or more detectable chemicals	Has a few non-critical interferents	Between 10 s and 60 s	Between 30 s and 59 s	Detects chemicals in two states	Audible alarm only	Between 2 lbs and 5 lbs and handheld		Battery powered			Between \$500 and \$2K per unit		Less than 4 h training required
◑	Detects either the nerve or blister agent class	Detects one TIM	Detects at IDLH for all detectable chemicals	May respond to common battlefield interferents		Between 1 min and 5 min	Detects chemicals in one state	Visible alarm only	Between 5 lbs and 10 lbs	Operates on standard, inexpensive, and readily available batteries for 2 h of continuous use		Operates in most environments	Able to operate after being moved but not after rough handling	Between \$2K and \$5K per unit	No special skills but training required	Less than 8 h training required
◒			Detects at IDLH for one or more detectable chemicals	Has many interferents	Between 60 s and 2 min	Between 5 min and 30 min		Alternate alarm type	Between 10 lbs and 50 lbs		Vehicle or ac powered					
○	Detects none of the nerve or blister agents	Detects none of the TIMs listed	Does not detect IDLH levels	Does not discriminate between chemical agents/TIMs and interferents	Greater than 2 min	More than 30 min	No capability	No capability	Greater than 50 lbs	Operates on special order and expensive batteries	Powered by ac	Operation is restricted to certain environments	Must remain stationary	More than \$5K per unit	Technician required to operate equipment	More than 8 h training required

The empty cells designate that the symbol is not applicable for the selection factor.

## **APPENDIX A—RECOMMENDED QUESTIONS ON DETECTORS**



## **Recommended Questions on Detector Equipment<sup>1</sup>**

Buying detection, protection, and decontamination equipment to respond to the threatened terrorist use of chemical or biological warfare agents may be new for Public Safety Agencies. To help procurement officials obtain the best value for their domestic preparedness dollar, the staff of the Center for Domestic Preparedness (Fort McClellan, AL), Military Chemical/Biological Units, the National Institute of Justice, and members of a federal Interagency Board (that includes representatives from the state and local law enforcement, medical, and fire communities) have compiled a series of questions. These questions should assist officials in selecting products from the large number in the present day marketplace. Requesting vendors to provide written responses to your specific questions may also be helpful in the decision process.

1. What agents has the equipment been tested against?
2. Who conducted the tests? Have the test results been verified by an independent laboratory or only by the manufacturer? What were the results of those tests?
3. What common substances cause a “false positive” reading or interference?
4. Is the test data available? Where?
5. What types of tests were conducted? Have any engineering changes or manufacturing process changes been implemented since the testing? If so, what were the changes?
6. Can the equipment detect both large and small agent concentrations?
7. Are there audible and visual alarms? What are their set points and how hard is it to change them? Are the alarm set points easily set to regulatory or physiologically significant values?
8. How quickly does the detector respond to a spike in the agent concentration? How quickly does the detector clear when taken to a clean area? What is the response time of the detector to a spike in the agent? How much time does the detector take to clear when taken to a clean area?
9. How long does it take to put the equipment into operation? Can it be efficiently operated by someone in a Level A suit?
10. How long do the batteries last? How long does it take to replace batteries or recharge? What is the cost of new batteries? Are the expended batteries hazardous materials and what is the cost of disposal of batteries?
11. How long has the company/manufacturer been involved with the Chem-Bio-Nuc and first responder industries? You may also ask for references.
12. Is the company currently supplying its product(s) to similar agencies? If so, who? Ask for names and phone numbers of departments currently using the company’s equipment. Ask to follow-up on the phone any written testimonials.
13. What additional items are required to operate/maintain the equipment? At what cost? What training materials are provided—manuals, videotapes, CD ROMs? What is the cost of training materials?
14. What type of warranty/maintenance support is offered? Cost?
15. What is the return rate on the equipment under warranty? What are the top five reasons for failure?
16. What are the required on-hand logistical support and costs? How often does the equipment need to be sent back to the manufacturer for maintenance?

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<sup>1</sup> Information provided by the National Domestic Preparedness Office (NDPO) in coordination with the National Institutes of Justice and Technical Support Working Group.

17. How often does the equipment require calibration? Does calibration require returning the equipment to the manufacturer? Does the calibration involve hazardous materials?
18. What special licenses/permits/registrations are required to own/operate the equipment?
19. What similar companies' products has this product been tested against? What were the results of the tests? Compare it in cost and performance to M-8/M-9 paper.
20. What is the shelf life of the equipment (open exposed, open unexposed, closed exposed, closed unexposed)?
21. What is required to decontaminate the equipment if taken into the Hot Zone?
22. What capability does this equipment give me that I do not currently possess? What equipment can I do away with if I purchase this? Is it only used for military chemicals?
23. Does this equipment require any hazardous materials for cleaning? If yes, what are they?
24. Taking weight and size into consideration, what procedures/process are needed to employ down range? How hard is it to decontaminate to get it out of the Hot Zone? What procedures/process are employed to decontaminate to remove from the Hot Zone?
25. What is the theory of operation? Surface acoustic wave (SAW) photo ionization, flame ionization, etc.
26. What are the environmental limitations—high temperature, low temperature, humidity, sand/dust?
27. What are the storage requirements (i.e., refrigerators, cool room, or no special requirements)?
28. What training is required to use the equipment and interpret the results? Does the company provide this training, and what is the cost? How often is refresher training required?

## **APPENDIX B—REFERENCES**





## APPENDIX B—REFERENCES

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